

Appendix A

Description of Geologic Units

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APPENDIX A: Description of GIS Geologic Units, Platte River Basin

This appendix describes the 115 digital Geographic Information System (GIS) geologic units that comprise the Platte River Basin of Wyoming, Colorado, and Nebraska. The stratigraphic descriptions in this appendix are for the units shown on **Plate I**. The 115 digital GIS geologic units are distributed as follows:

<i>Wyoming</i>	<i>82 geologic units</i>	<i>page A1-11</i>
<i>Colorado</i>	<i>27 geologic units</i>	<i>page A11-13</i>
<i>Nebraska</i>	<i>6 geologic units</i>	<i>page A1-11</i>

These geologic units are compiled from the 1:500,000-scale digital state maps that cover the Platte River Basin. The maps give a code and rock-type description to each unit within the mapped state; each state has its own set of codes, and neither codes nor unit boundaries necessarily match across state lines.

In this appendix, for each state, each geologic unit symbol (**bold face**) and GIS definition (underlined) is followed by a description of the corresponding stratigraphic unit(s) as defined in that state. **Plate 1** summarizes these determinations. The abbreviation “Ma” in the following descriptions denotes “million years before present.” Rock-stratigraphic units that appear in the right-hand column of **Plate 1 and 2** are in **boldface**.

PLATTE RIVER BASIN GEOLOGIC UNITS – WYOMING & NEBRASKA

There are 82 digital GIS geologic units in the Wyoming portion of the Platte River Basin and 6 digital GIS geologic units in the Nebraska portion (Love and Christiansen, 1985; Stoeser et al., 2005). The stratigraphic descriptions below are taken directly from Love and Christiansen (1985) with minor modifications.

References

- Love, J.D., and Christiansen, A.C., *compilers*, 1985, Geologic map of Wyoming: U.S. Geological Survey, scale 1:500,000, 3 sheets.
- Love, J.D., Christiansen, A.C., and Ver Ploeg, A.J., *compilers*, 1993, Stratigraphic chart showing the Phanerozoic nomenclature for the state of Wyoming: Geological Survey of Wyoming Map Series 41 (MS-41).
- Stoeser, D.B., Green, G.N., Morath, L.C., Heran, W.D., Wilson, A.B., Moore, D.W., Van Gosen, B.S., 2005, Preliminary integrated geologic map databases for the United States Central States – Montana, Wyoming, Colorado, New Mexico, Kansas, Oklahoma, Texas, Missouri, Arkansas, and Louisiana, North Dakota, South Dakota, Nebraska, and Iowa: U.S. Geological Survey Open-File Report 2005-1351, version 1.2, updated December 2007, digital data. [Includes Wyoming, Colorado, and Nebraska at 1:500,000-scale, though different states within this database have different scales.]

Symbol ***Unit Description***

CENOZOIC GEOLOGIC UNITS – WYOMING

Quaternary geologic units – Wyoming & Nebraska

- Qa** Alluvium and colluvium (Holocene-Pleistocene) – Clay, silt, sand, and gravel in flood plains, fans, terraces, and slopes.
- Qt** Gravel, pediment, and fan deposits (Holocene-Pleistocene) – Mostly locally derived clasts; locally includes some Tertiary gravels.
- Qg** Glacial deposits (Holocene-Pleistocene) – Till and outwash of sand, gravel, and boulders.

<i>Symbol</i>	<i>Unit Description</i>
Qls	<u>Landslide deposits</u> (Holocene-Pleistocene) – Local intermixed landslide and glacial deposits, talus, and rock-glacier deposits.
Qs	<u>Dune sand and loess</u> (Holocene-Pleistocene) (present in Nebr.) – Active and dormant sand dunes.
Ql	<u>Playa lake and other lacustrine deposits</u> (Holocene-Pleistocene) – Chiefly clay, silt, and fine sand. Includes travertine deposits.
Qu	<u>Undivided surficial deposits</u> (Holocene-Pleistocene) – Mostly alluvium, colluvium, and glacial and landslide deposits.
QTg	<u>Terrace gravel</u> (Pleistocene and (or) Pliocene) – Partly consolidated gravel above and flanking some major streams.
QTc	<u>Conglomerate</u> (Pleistocene to Miocene) – Giant granite boulders in arkose matrix.
QTb	<u>Bug Formation</u> (Pleistocene or Pliocene) – Lacustrine white marl, claystone, sandstone, conglomerate, and tuff; generally radioactive.

Upper Tertiary geologic units – Wyoming & Nebraska

Tm	<p><u>Miocene rocks (undivided)</u> (Miocene)</p> <p><u>Miocene rocks</u> – Central Wyoming – White soft tuffaceous sandstone; locally derived conglomerate in upper and lower parts of sequence; some lower conglomeratic sequences may be Oligocene; in Granite Mountains, K/Ar age of tuff in lower part of sandstone sequence ~17 Ma, fission-track age of lower conglomerate ~24 Ma.</p> <p><u>Miocene rocks</u> – Saratoga Valley and west and southwest to Colorado – White massive soft tuffaceous sandstone and lesser white marl; lower part conglomeratic. Underlies <u>North Park Formation</u> in Saratoga Valley. To the west and southwest is referred to as <u>Browns Park Formation</u>.</p> <p><u>Miocene rocks</u> – Rawlins Area – White massive soft tuffaceous sandstone.</p>
Tmu	<p><u>Upper Miocene rocks (undivided)</u> (upper Miocene)</p> <p><u>upper Miocene rocks</u> – Southeast corner of Wind River Range – Siliceous, arkosic, locally radioactive sandstone, claystone, and conglomerate; fission-track age ~27 Ma. Recent work suggests that part of these deposits may be of Eocene age. Originally defined as the Miocene-Pliocene South Pass Formation.</p> <p><u>upper Miocene rocks</u> – Saratoga Valley, <u>North Park Formation</u> – White to greenish-gray tuffaceous sandstone, siltstone, and claystone; locally conglomeratic.</p> <p><u>upper Miocene rocks</u> – Central Wyoming – Arkosic sandstone, conglomerate, and siltstone; some light-colored tuffaceous radioactive claystone and white cherty limestone.</p> <p><u>upper Miocene rocks</u> – Central Wyoming, <u>Moonstone Formation</u> - North of Sweetwater River in Granite Mountains – Light-colored tuffaceous radioactive claystone, siltstone, sandstone, and arkose.</p> <p><u>upper Miocene rocks</u> – East Wyoming – Light-colored tuffaceous claystone, sandstone, and conglomerate. <u>Ogallala Formation</u> in Denver Basin.</p>
Tml	<p><u>Lower Miocene rocks</u> (Lower Miocene) – Central Wyoming – Tuffaceous sandstone, siltstone, and white marl.</p>

<i>Symbol</i>	<i>Unit Description</i>
Tmo	<u>Lower Miocene and upper Oligocene rocks</u> (Miocene and upper Oligocene) – Light-colored soft porous sandstone and underlying white tuffaceous claystone and siltstone. <u>Arikaree Formation</u> in Denver Basin.
Tu	<u>Sandstone and Conglomerate</u> (Post Eocene) – Gray, hard, coarse-grained sandstone and conglomerate.
Lower Tertiary geologic units – Wyoming & Nebraska	
Twr	<u>White River Formation</u> (Oligocene; 31-35 Ma) (present in Nebr.) – White to pale-pink, blocky, tuffaceous claystone and lenticular arkosic conglomerate.
Twru	<u>Upper conglomerate member, White River Formation</u> (Oligocene) – Light-gray, soft, conglomeratic, tuffaceous sandstone and conglomerate of Precambrian clasts.
Twrb	<u>Brule Member, White River Formation</u> (Oligocene) – Pale-pink to white blocky tuffaceous claystone and lenticular sandstone. Locally includes the upper conglomerate member.
Twrc	<u>Chadron Member, White River Formation</u> (Oligocene) – Light gray to dark-red, tuffaceous claystone, sandstone, and lenticular conglomerate.
Toe	<u>Oligocene and (or) Upper and Middle Eocene rocks</u> (Oligocene and Eocene) – Light gray tuff, arkosic sandstone, and lenticular conglomerate.
Tid	<u>Dacite and quartz latite intrusive and extrusive igneous rocks</u> (Oligocene and (or) Eocene ~44Ma) – Light gray porphyritic rock.
Tip	<u>Ice Point Conglomerate</u> (Eocene) – Reddish-brown conglomerate, chiefly of Paleozoic rock fragments.
Twb	<u>Wagon Bed Formation</u> (Eocene; ~45-49 Ma) – Central Wyoming – Dull-green, siliceous, bentonitic claystone and tuff; giant granite boulder conglomerate in tuffaceous matrix.
Tb	<u>Bridger Formation</u> (Eocene) – Greenish-gray, olive-drab, and white tuffaceous sandstone and claystone; lenticular marlstone and conglomerate.
Tcg	<u>Crooks Gap Conglomerate</u> (Eocene) – Giant boulders of granite in arkosic sandstone matrix. Reynolds (1976) considers age of eastern exposure to be Oligocene (?).
Tai	<u>Alkalic intrusive and extrusive igneous rocks</u> (Eocene ~44Ma) – Light- to greenish-gray porphyry.
Tgl	<u>Laney Member, Green River Formation</u> (Eocene ~45Ma) – Oil shale and marlstone.
Tgt	<u>Tipton shale Member or Tongue, Green River Formation</u> (Eocene) – Oil shale and marlstone.
Tw	<u>Wasatch Formation</u> (Eocene) – East Wyoming – Drab sandstone and drab to variegated claystone; numerous coal beds in lower part.
Twc	<u>Cathedral Bluffs Tongue, Wasatch Formation</u> (Eocene) – Variegated claystone and lenticular sandstone; conglomeratic near south margin of Wind River Range.

<i>Symbol</i>	<i>Unit Description</i>
Twm	<u>Main body, Wasatch Formation</u> (Eocene-Paleocene) – Drab sandstone, drab to variegated claystone, and siltstone; locally derived conglomerate around basin margins. Lower part is Paleocene.
Tbw	<u>Transitional unit between Battle Springs and Wasatch Formations</u> (Eocene) – Interbedded lithologies of <u>Battle Spring</u> and <u>Wasatch</u> Formations.
Tbs	<u>Battle Spring Formation</u> (Eocene-upper Paleocene) – Equivalent to, and lithologically similar to locally derived basin-margin conglomerate of Wasatch Formation; merges southward into main body of Wasatch Formation. Lower part is Paleocene.
Twdr	<u>Wind River Formation</u> (Eocene) – Central Wyoming – Variegated claystone and sandstone; lenticular conglomerate. Age of tuff at top 49 Ma.
Tim	<u>Indian Meadows Formation</u> (Eocene) – Red to variegated claystone, sandstone, and algal-ball limestone; some beds of large Paleozoic boulders and detachment masses of Paleozoic and Mesozoic rocks.
Tco	<u>Coalmont Formation</u> (Eocene and Paleocene) – Tan to gray, arkosic, micaceous, soft sandstone, claystone, and locally derived conglomerate.
Tha	<u>Hanna Formation</u> (Paleocene) – Brown and gray sandstone, shale, conglomerate, and coal; giant quartzite boulders near Medicine Bow Mountains.
Tfu	<u>Fort Union Formation</u> (Northwest, southwest, and central Wyoming) – Brown and gray sandstone, gray to black shale, and thin coal beds.
Tfl	<u>Lebo Member, Fort Union Formation</u> – Dark-gray clay shale and concretionary sandstone.
Tft	<u>Tullock Member, Fort Union Formation</u> – Soft, gray sandstone, gray and brown carbonaceous shale, and thin coal beds.
TKf	<u>Ferris Formation</u> (Paleocene and Upper Cretaceous) – Brown and gray sandstone and shale; sparse carbonaceous shale and coal beds; thin lenses of pebble conglomerate.

MESOZOIC GEOLOGIC UNITS – WYOMING

Upper Cretaceous geologic units – Wyoming

Kl	<u>Lance Formation</u> (Upper Cretaceous) – South and northeast Wyoming – Brown and gray sandstone and shale; thin coal and carbonaceous shale beds.
Klm	<u>Lance Formation and Lewis Shale</u> (Upper Cretaceous) <u>Lance Formation</u> – South and northeast Wyoming – Brown and gray sandstone and shale; thin coal and carbonaceous shale beds. <u>Lewis Shale</u> – Gray marine shale containing abundant interbedded gray and brown lenticular concretion-rich sandstone beds.
Kmb	<u>Medicine Bow Formation</u> (Upper Cretaceous) – Brown and gray sandstone and shale; thin coal and carbonaceous shale beds.

<i>Symbol</i>	<i>Unit Description</i>
Kfh	<u>Fox Hills Sandstone</u> (Upper Cretaceous) – Light-colored sandstone and gray sandy shale containing marine fossils.
Kfl	<u>Fox Hills Sandstone and Lewis Shale</u> (Upper Cretaceous) <u>Fox Hills Sandstone</u> – Light-colored sandstone and gray sandy shale containing marine fossils. <u>Lewis Shale</u> – Gray marine shale containing abundant interbedded gray and brown lenticular concretion-rich sandstone beds.
Kml	<u>Meeteetse Formation and Lewis Shale</u> (Upper Cretaceous) <u>Meeteetse Formation</u> (~73 Ma) – Chalky-white to gray sandstone, yellow, green, and dark-gray bentonitic claystone, white tuff, and thin coal beds. <u>Lewis Shale</u> (~68 Ma) – Gray marine shale containing abundant interbedded gray and brown lenticular concretion-rich sandstone beds.
Kle	<u>Lewis Shale</u> (Upper Cretaceous; ~68 Ma) – Gray marine shale containing abundant interbedded gray and brown lenticular concretion-rich sandstone beds.
Kmv	<u>Mesaverde Formation or Group</u> (Upper Cretaceous) – Light-colored, massive to thin-bedded sandstone, gray sandy shale, and coal beds. <u>Rawlins Uplift</u> (South Wyoming) (Upper Cretaceous) <u>Almond Formation</u> – White and brown, soft sandstone, gray sandy shale, coal and carbonaceous shale. <u>Pine Ridge Sandstone</u> – Light gray sandstone and thin coal beds. <u>Allen Ridge Formation</u> – Gray sandstone, shale, and thin coal beds. <u>Haystack Mountains Formation</u> – Gray marine sandstone and shale. <u>Laramie Basin</u> (South Wyoming) (Upper Cretaceous) <u>Pine Ridge Sandstone</u> – Light gray sandstone and thin coal beds. <u>Rock River Formation</u> – Soft sandstone and sandy shale.
Kc	<u>Cody Shale</u> (Upper Cretaceous; 78-83 Ma) – South Wyoming – Dull-gray shale, gray siltstone, and fine-grained gray sandstone.
Kf	<u>Frontier Formation</u> (Upper Cretaceous) – South Wyoming – Gray sandstone and sandy shale.
Kcf	<u>Cody Shale and Frontier Formation</u> (Upper Cretaceous) <u>Cody Shale</u> – South Wyoming – Dull-gray shale, gray siltstone, and fine-grained gray sandstone. <u>Frontier Formation</u> – South Wyoming – Gray sandstone and sandy shale.
Knt	<u>Niobrara and Frontier Formations, and Mowry and Thermopolis Shales</u> (Upper Cretaceous) <u>Niobrara Formation</u> (Upper Cretaceous: ~ 83 Ma) – Light-colored limestone and gray to yellow speckled limy shale. <u>Frontier Formation</u> – South Wyoming – Gray sandstone and sandy shale. <u>Mowry Shale</u> (Upper Cretaceous) – Silvery-gray, hard, and siliceous shale containing abundant fish scales and bentonite beds. <u>Thermopolis Shale</u> (Lower Cretaceous) – Black, soft, and fissile shale with Muddy Sandstone Member at top of unit.
Kft	<u>Frontier Formation and Mowry and Thermopolis Shales</u> (Upper Cretaceous) <u>Frontier Formation</u> – South Wyoming – Gray sandstone and sandy shale.

<i>Symbol</i>	<i>Unit Description</i>
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Kft (cont.)

Mowry Shale (Upper Cretaceous) – Silvery-gray, hard, and siliceous shale containing abundant fish scales and bentonite beds.

Thermopolis Shale (Lower Cretaceous) – Black, soft, and fissile shale with Muddy Sandstone Member at top of unit.

Ks Steele Shale (Upper Cretaceous; ~78 to 82 Ma) – Gray, soft, marine shale containing numerous bentonite beds and thin lenticular sandstone.

Ksn Steele Shale and Niobrara Formation (Upper Cretaceous)
Steele Shale (Upper Cretaceous: ~78 to 82 Ma) – Gray, soft, marine shale containing numerous bentonite beds and thin lenticular sandstone.
Niobrara Formation (Upper Cretaceous: ~ 83 Ma) – Light-colored limestone and gray to yellow speckled limy shale.

Kp Pierre Shale (Upper Cretaceous: ~72-78 Ma) – Dark-gray, concretionary, marine shale; contains several bentonite beds.

Kn Niobrara Formation (Upper Cretaceous: ~83 Ma) – Light-colored limestone and gray to yellow speckled limy shale.

Lower Cretaceous geologic units – Wyoming

Kmt Mowry and Thermopolis Shales (Upper to Lower Cretaceous)
Mowry Shale (Upper Cretaceous) – Silvery-gray, hard, siliceous shale containing abundant fish scales and bentonite beds.
Thermopolis Shale (Lower Cretaceous) – Black soft fissile shale with Muddy Sandstone Member at top of unit.

Cretaceous and Jurassic geologic units – Wyoming

KJ Cloverly and Morrison Formations (Lower Cretaceous to Jurassic)
Cloverly Formation – Rusty-color sandstone at top, underlain by brightly variegated bentonitic claystone; chert-pebble conglomerate locally at base.
Morrison Formation – Dully variegated, siliceous claystone, nodular white limestone, and gray silty sandstone.

KJs Cloverly, Morrison, and Sundance Formations (Lower Cretaceous to Jurassic)
Cloverly Formation – Rusty-color sandstone at top, which overlies brightly variegated bentonitic claystone; chert-pebble conglomerate locally at the base.
Morrison Formation – Dully variegated, siliceous claystone, nodular white limestone, and gray silty sandstone.
Sundance Formation – Greenish-gray glauconitic sandstone and shale, underlain by red and gray non-glauconitic sandstone and shale.

Jurassic geologic unit – Wyoming

Js Sundance Formation (Upper Jurassic to Middle Jurassic) – Greenish-gray, glauconitic sandstone and shale, underlain by red and gray non-glauconitic sandstone and shale.

Jurassic and Triassic geologic unit – Wyoming

JFn Nugget Sandstone (Jurassic to Triassic (?)) – North Wyoming – Gray to dull-red, crossbedded, quartz-rich sandstone.

Triassic geologic units – Wyoming

<i>Symbol</i>	<i>Unit Description</i>
<u>Tc</u>	<u>Chugwater Group or Formation</u> (Upper and Lower Triassic) <u>Chugwater Formation</u> (Upper and Lower Triassic) – Red siltstone and shale. <u>Alcova Limestone Member</u> in upper middle part in north Wyoming. Thin gypsum partings near base in north and northeastern Wyoming. <u>Chugwater Group or Formation</u> (Upper and Lower Triassic) – Red shale and siltstone containing thin gypsum partings near base. Group includes <u>Popo Agie Formation</u> (red shale and red, yellow, and purple siltstone; lenses of lime-pellet conglomerate), <u>Crow Mountain Sandstone</u> (red and gray, thick bedded), <u>Alcova Limestone</u> , and <u>Red Peak Formation</u> (red siltstone and shale). <u>Chugwater Formation</u> includes as members all the units listed above.
<u>Tcd</u>	<u>Chugwater and Dinwoody Formations</u> (Upper and Lower Triassic) <u>Chugwater Formation</u> – Red siltstone and shale. <u>Alcova Limestone Member</u> in upper middle part in north Wyoming. Thin gypsum partings near base in north and northeast Wyoming. <u>Dinwoody Formation</u> – North Wyoming – Olive-drab hard dolomitic thin-bedded siltstone.

MESOZOIC AND PALEOZOIC GEOLOGIC UNITS – WYOMING

<u>MzPz</u>	<u>Mesozoic and Paleozoic rocks</u> (Mesozoic to Paleozoic) – South Wyoming – Mapped in small local areas of complex structure. South side of Granite Mountains north of Green Mountain – <u>Nugget Sandstone</u> , <u>Chugwater and Goose Egg Formations</u> , <u>Tensleep Sandstone</u> , and <u>Amsden Formation</u> (Jurassic (?) through Mississippian) South flank of Ferris Mountains – <u>Nugget Sandstone and Chugwater and Goose Egg Formations</u> (Jurassic (?) through Permian) Northeast flank of Seminoe Mountains – <u>Cloverly, Morrison, Sundance, Chugwater and Goose Egg Formations</u> (Lower Cretaceous through Permian) East flank of Laramie Mountains – <u>Cloverly, Morrison, Sundance, Chugwater, and Goose Egg Formations</u> , and east of fault in T. 19 N., <u>Casper Formation</u> (Lower Cretaceous through Middle Pennsylvanian)
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Triassic and Permian geologic units – Wyoming

<u>TPcg</u>	<u>Chugwater and Goose Egg Formations</u> (Upper Triassic-Permian) <u>Chugwater Formation</u> (Upper and Lower Triassic) – Red siltstone and shale. <u>Alcova Limestone Member</u> in upper middle part in north Wyoming. Thin gypsum partings near base in north and northeastern Wyoming. <u>Goose Egg Formation</u> – Red sandstone and siltstone, white gypsum, halite, and purple to white dolomite and limestone.
<u>TPjs</u>	<u>Jelm and Chugwater Formations, Forelle Limestone, and Satanka Shale</u> (Lower Triassic-Permian) <u>Jelm Formation</u> – Red sandstone. <u>Chugwater Formation</u> (Upper and Lower Triassic) – Red siltstone and shale. <u>Alcova Limestone Member</u> in upper middle part in north Wyoming. Thin gypsum partings near base in north and northeastern Wyoming. <u>Forelle Limestone</u> – Thin-bedded limestone. Locally a member of the Goose Egg Formation. <u>Satanka Shale</u> – Red shale.

<i>Symbol</i>	<i>Unit Description</i>
RPg	<u>Goose Egg Formation</u> (Lower Triassic-Permian) – Red sandstone and siltstone, white gypsum, halite, and purple to white dolomite and limestone.

PALEOZOIC GEOLOGIC UNITS – WYOMING

Pzr	<u>Paleozoic Rocks</u> (Permian-Cambrian) – Rattlesnake Hills, east end of Granite Mountains, and north end of Laramie Mountains consists of <u>Madison Limestone</u> and <u>Cambrian rocks</u> .
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Permian geologic units – Wyoming

Pp	<u>Phosphoria Formation and related rocks</u> (Permian) – Brown sandstone and dolomite, cherty, phosphatic, and glauconitic dolomite, phosphatic sandstone and dolomite, and greenish-gray to black shale; intertonguing equivalents of parts of Phosphoria are <u>Park City Formation</u> (primarily cherty dolomite, limestone, and phosphatic gray shale) and <u>Shedhorn Sandstone</u> .
Pfs	<u>Forelle Limestone and Satanka Shale</u> (Permian) <u>Forelle Limestone</u> – Thin-bedded limestone. Locally a member of the Goose Egg Formation. <u>Satanka Shale</u> – Red shale.

Permian and Pennsylvanian geologic units – Wyoming

PPc	<u>Casper Formation</u> (Lower Permian-Upper and Middle Pennsylvanian) – Gray, tan, and red thick-bedded sandstone underlain by interbedded sandstone and pink and gray limestone. May include some Devonian (?) sandstone along east flank of Laramie Mountains.
PPcf	<u>Casper and Fountain Formations</u> (Lower Permian-Upper and Middle Pennsylvanian) <u>Casper Formation</u> – Gray, tan, and red thick-bedded sandstone underlain by interbedded sandstone and pink and gray limestone. May include some Devonian (?) sandstone along east flank of Laramie Mountains. <u>Fountain Formation</u> – Arkose and red sandstone.
PPM	<u>Casper Formation and Madison Limestone</u> (lower Permian-Upper Mississippian) <u>Casper Formation</u> – Gray, tan, and red thick-bedded sandstone underlain by interbedded sandstone and pink and gray limestone. May include some Devonian (?) sandstone along east flank of Laramie Mountains. <u>Madison Limestone or Group</u> – Group includes Mission Canyon Limestone (blue-gray, massive limestone and dolomite), underlain by Lodgepole Limestone (gray cherty limestone and dolomite).
PPh	<u>Hartville Formation</u> (Lower Permian-Upper, Middle, and Lower Pennsylvanian) – Red and white sandstone underlain by gray dolomite and limestone, red shale, and red and gray sandstone. Lowermost unit may be Late Mississippian in age.

Permian and Mississippian geologic units – Wyoming

PM	<u>Tensleep Sandstone and Amsden Formation</u> (lower Permian to Upper Mississippian) <u>Tensleep Sandstone</u> (Lower Permian to Upper Mississippian) – South Wyoming – White to gray sandstone containing thin limestone and dolomite beds.
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<i>Symbol</i>	<i>Unit Description</i>
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PM (cont.)

Amsden Formation (lower Permian to Middle Pennsylvanian) – South Wyoming – Red and green shale and dolomite with a persistent red to brown sandstone at base.

Mississippian geologic units – Wyoming

Mm Madison Limestone or Group (Upper to Lower Mississippian) – Group includes Mission Canyon Limestone (blue-gray, massive limestone and dolomite), underlain by Lodgepole Limestone (gray, cherty limestone and dolomite).

Mississippian and Devonian geologic units – Wyoming

MDg Guernsey Formation (Lower Mississippian and Upper Devonian) – Blue-gray massive cherty limestone and dolomite. Locally includes unnamed dolomite and sandstone of Devonian and Cambrian (?) age.

Ordovician and Cambrian geologic units – Wyoming

O€ Bighorn Dolomite, Gallatin Limestone, Gros Ventre Formation, and Flathead Sandstone (Upper Ordovician to Middle Cambrian)
Bighorn Dolomite (Upper to Middle Ordovician) – Gray, cliff-forming, siliceous, massive dolomite and locally dolomitic limestone.
Gallatin Limestone (Upper Cambrian) – Gray and tan limestone.
Gros Ventre Formation (Upper to Middle Cambrian) – Soft, green, micaceous shale (Upper and Middle Cambrian Park Shale Member), underlain by blue-gray and yellow mottled, hard, dense limestone (Middle Cambrian Death Canyon Limestone Member), and soft, green, micaceous shale (Middle Cambrian Wolsey Shale Member).
Flathead Sandstone (Middle Cambrian) – Dull-red, quartz-rich sandstone.

Cambrian geologic units – Wyoming

€r Cambrian rocks (Middle to Upper Cambrian) – Hard, blue-gray and yellow mottled, dense limestone interbedded with soft, green micaceous shale; dull-red quartz-rich sandstone at base.

PRECAMBRIAN GEOLOGIC UNITS – WYOMING

p€r Precambrian rocks – Middle Proterozoic through middle Archean granitic, metasedimentary, metavolcanic, and mafic intrusive rocks.
Sherman Granite (Middle Proterozoic, 1,415-1,435 Ma.) – In Medicine Bow and Laramie Mountains.
Laramie Anorthosite Complex (Middle Proterozoic) – In Laramie Mountains – Pyroxene and hornblende syenite – Age 1,435 Ma.
Laramie Anorthosite Complex (Middle Proterozoic) – In Laramie Mountains – Anorthosite and norite.
Metasedimentary and Metavolcanic rocks (Early Proterozoic)
Sierra Madre – Granite gneiss, felsic gneiss, amphibolite, and metavolcanic rocks
Medicine Bow Mountains – Granite gneiss, felsic gneiss, hornblende gneiss, and amphibolite.
Laramie Mountains – Pelitic Schist, marble, granite gneiss, layered amphibolite, and felsic gneiss.

Symbol
pCr (cont.)

Unit Description

Metasedimentary rocks (Early Proterozoic) – In Medicine Bow Mountains and Sierra Madre – Libby Creek Group – Pelitic schist, amphibole schist, quartzite diamictite, quartz-pebble conglomerate, and marble.

Metasedimentary rocks (Early Proterozoic) – In Medicine Bow Mountains and Sierra Madre – Deep Lake Group – Quartzite, diamictite, pelitic schist, and quartz-pebble conglomerate.

Granitic rocks of 1,700 Ma Age Group (Early Proterozoic) – In Sierra Madre and Medicine Bow Mountains, and Hartville Uplift.

Quartz diorite (Early Proterozoic)

Sierra Madre – Encampment River Granodiorite (1,800 Ma).

Medicine Bow Mountains – Keystone Quartz Diorite

Hartville Uplift – Diorite of Twin Hills.

Mafic intrusive rocks (Early Proterozoic)

Sierra Madre – Gabbro of Elkhorn Mountain (1,800 Ma).

Medicine Bow Mountains – Mullen Creek and Lake Owens Mafic Complexes; older than 1,700 Ma.

Granitic rocks of 2,000 Ma Age Group (Early Proterozoic)

Medicine Bow Mountains – Gaps Intrusion (granitic).

Hartville uplift – Granite and quartz monzonite of Flattop Butte, age 2,150± Ma.

Mafic Intrusive Rocks (Proterozoic and Late Archean) – In Sierra Madre and Medicine Bow Mountains.

Granite gneiss (Late Archean, 2,600-3,100+ Ma) – Layered to massive, locally migmatitic; metasedimentary and metavolcanic rocks locally common.

Metasedimentary and metavolcanic rocks – Amphibolite, hornblende gneiss, biotite gneiss, quartzite, iron-formation, metaconglomerate, marble, and pelitic schist; locally preserved textures and structures suggest origin to be sedimentary or volcanic. Older than 3,200 Ma in Granite Mountains; older than 2,600 Ma in Medicine Bow Mountains and Sierra Madre, where it is the Late Archean Phantom Lake Metamorphic Suite.

Metasedimentary and Metavolcanic rocks (Late Archean)

Metasedimentary rocks

Wind River Range – Metagraywacke, pelitic schist, metaconglomerate, graphitic schist, and iron-formation; local meta-andesite. At least 2,800Ma.

Seminole Mountains (southeast end of Granite Mountains) – Pelitic schist, quartzite, and iron-formation.

Casper Mountain (northwest extension of Laramie Mountains) – Felsic gneiss, quartzite, and iron-formation.

Laramie Mountains – Pelitic schist, iron-formation, quartzite, marble, metaconglomerate, and metagraywacke.

Metasedimentary and Metavolcanic rocks (Late Archean)

Metamorphosed mafic and ultramafic rocks

Bighorn and Granite Mountains – Amphibolite.

Seminole Mountains – Amphibolite of volcanic origin, komatiite, and metagabbro.

Casper Mountain – Amphibolite and serpentinite.

Laramie Mountains – Amphibolite of volcanic origin, komatiite (?), metagabbro, and ultramafic sills.

Peridotite intrusive rocks (Late Archean) – In Laramie Mountains.

Symbol ***Unit Description***

pCr (cont.)

Granitic rocks of 2,600-Ma Age Group (Late Archean, 2,600 Ma)
Sierra Madre – Granite and granodiorite.
Laramie Mountains – Granite, amphibolite, and minor amounts of metasedimentary rocks.
Hartville uplift – Granite and quartz monzonite.

PLATTE RIVER BASIN GEOLOGIC UNITS – COLORADO

There are 27 digital GIS geologic units in the Colorado portion of the Platte River Basin (Tweto and Schoenfeld, 1979). The stratigraphic descriptions below are taken directly from Tweto and Schoenfeld (1979) with minor modifications.

References

Stoeser, D.B., Green, G.N., Morath, L.C., Heran, W.D., Wilson, A.B., Moore, D.W., Van Gosen, B.S., 2005, Preliminary integrated geologic map databases for the United States Central States – Montana, Wyoming, Colorado, New Mexico, Kansas, Oklahoma, Texas, Missouri, Arkansas, and Louisiana, North Dakota, South Dakota, Nebraska, and Iowa: U.S. Geological Survey Open-File Report 2005-1351, version 1.2, updated December 2007, digital data. [Includes Wyoming, Colorado, and Nebraska at 1:500,000-scale, though different states within this database have different scales.]

Tweto, Ogden, and R. E. Schoenfeld, 1979, *Geologic map of Colorado*. [Reston, Va.]: Dept. of the Interior, United States Geological Survey, scale 1:500,000, 2 sheets.

Symbol ***Unit Description***

CENOZOIC GEOLOGIC UNITS – COLORADO

Quaternary geologic units – Colorado

- Qa** Modern alluvium (Holocene) – Includes Piney Creek Alluvium and younger deposits.
- Qg** Gravels and alluviums (Pinedale and Bull Lake age) (Pleistocene) – Includes Broadway and Louviers Alluviums.
- Qgo** Older gravels and alluviums (Pre-Bull Lake age) (Pleistocene) – Includes Slocum, Verdos, Rocky Flats, and Nussbaum Alluviums in the east.
- Qe** Eolian deposits (Holocene-Pleistocene) – Includes dune sand and silt and Peoria Loess.
- Qd** Glacial drift of Pinedale and Bull Lake Glaciations (Pleistocene) – Includes some unclassified glacial deposits.
- Qdo** Older glacial drift (Pre-Bull Lake age)
- Ql** Landslide deposits (Holocene-Pleistocene) – Locally includes talus, rock-glacier, and thick colluvial deposits.

Symbol ***Unit Description***

Upper Tertiary geologic units – Colorado

- Tgv** Bouldery gravel on old erosion surfaces in Front Range and Never Summer Mountains
(Pliocene (?)-Miocene)
- To** Ogallala Formation (Pliocene(?)-Miocene) – Loose to well-cemented sand and gravel.
- Tnp** North Park Formation (Miocene) – Sandstone, siltstone, and conglomerate; in North Park and Laramie basin
- Tv** Volcanic rock in northwestern Colorado (age <7-33 Ma) – Mainly of intermediate composition.
- Tui** Upper Tertiary intrusive rocks (age <20 Ma) – Intermediate to felsic compositions.
- Taf** Ash-flow tuff of main volcanic sequence (age 29-32 Ma) – Includes many named units.
- Tmi** Middle Tertiary intrusive rocks (age 20-40 Ma) – Intermediate to felsic compositions.

Lower Tertiary geologic units – Colorado

- Twr** White River Formation (Oligocene) – Ashy claystone and sandstone; in North Park.
- Tc** Coalmont Formation (Eocene-Paleocene) – Arkosic sandstone, conglomerate, and shale; coal in the lower part; in North Park.

MESOZOIC GEOLOGIC UNITS – COLORADO

Upper Cretaceous geologic units – Colorado

- Kp** Pierre Shale (Upper Cretaceous) – Undivided; sandstone with shale between zones of *Baculites reesidei* and *B. scotti*; organic-rich shale and numerous bentonite beds.
- Kc** Colorado Group (Upper & Lower Cretaceous) – Consists of Niobrara Formation (Kn) and either Benton Shale or Carlile, Greenhorn, and Graneros Formations (Kcg).
Niobrara Formation (Upper Cretaceous) – Calcareous shale and limestone.
Carlile Shale, Greenhorn Limestone, and Graneros Shale (Upper & Lower Cretaceous)

Lower Cretaceous geologic units – Colorado

- Kd** Dakota Sandstone or Group (Lower Cretaceous)
- Mz** Mesozoic rocks – Mainly Lower Cretaceous, Jurassic, and Triassic formations.

Cretaceous and Jurassic geologic units – Colorado

- KJdm** Dakota and Morrison Formations (Cretaceous & Jurassic)
Dakota Formation (Lower Cretaceous)
Morrison Formation (Upper Jurassic) – Variegated claystone, mudstone, sandstone, and local beds of limestone.

<i>Symbol</i>	<i>Unit Description</i>
KJds	<u>Dakota, Morrison, and Sundance Formations</u> (Cretaceous & Jurassic) <u>Dakota Formation</u> (Lower Cretaceous) <u>Morrison and Sundance Formations</u> (Upper Jurassic) – Sandstone, shale, claystone, and limestone.

Triassic geologic units – Colorado

Tch	<u>Chugwater Formation</u> (Lower Triassic) – Red sandstone, siltstone, shale, and local limestone and gypsum.
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MESOZOIC AND PALEOZOIC UNITS – COLORADO

MzPz	<u>Mesozoic and Paleozoic rocks</u> – Mainly as in Mesozoic unit (Mz) plus Permian and Pennsylvanian formations
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Triassic and Permian geologic units – Colorado

TPr	<u>Triassic and Permian rocks</u> (Triassic & Permian) – Red siltstone, shale, and sandstone. Includes various combinations of Nugget, Jelm, Popo Agie, Chugwater, Red Peak, Forelle, Satanka, and Goose Egg Formations near Wyoming border.
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PALEOZOIC GEOLOGIC UNITS – COLORADO

Permian and Pennsylvanian geologic units – Colorado

PPcf	<u>Casper Formation</u> (Sandstone) and lower part of <u>Fountain Formation</u> (Lower Permian & Upper & Middle Pennsylvanian)
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PRECAMBRIAN GEOLOGIC UNITS – COLORADO

pCr	<u>Precambrian rocks</u> – Proterozoic metamorphic and igneous rocks. <u>Granitic rocks of 1,400 M.Y. age group</u> (age 1,350-1,480 M.Y.) – Includes Silver Plume, Sherman, Cripple Creek, St. Kevin, Vernal Mesa, Curecanti, Eolus, and Trimble Granites or Quartz Monzonites; also San Isabel Granite of Boyer (1962) and unnamed granitic rocks. <u>Granitic rocks of 1,700 M.Y. age group</u> (age 1,650-1,730 M.Y.) – Includes Boulder Creek, Cross Creek, Denny Creek, Kroenke, Browns Pass, Powderhorn, Pitts Meadow, Bakers Bridge, and Tenmile Granites, Quartz Monzonites, or Granodiorites; also, unnamed granitic rocks. <u>Mafic rocks of 1,700 M.Y. age group</u> – Gabbro and mafic diorite and monzonite. <u>Biotitic gneiss, schist, and migmatite</u> Locally contains minor hornblende gneiss, calc-silicate rock, quartzite, and marble. Derived principally from sedimentary rocks. <u>Felsic and hornblendic gneisses, either separate or interlayered</u> – metabasalt, metatuff, and interbedded metagraywacke; locally contains interlayered biotite gneiss. Derived principally from volcanic rocks.
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Appendix B

WWDC Groundwater Studies

Brett Worman, and Karl Taboga

Appendix B WWDC Groundwater Studies.

Citation(s)	Location	Aquifer/ Formation	Project Description	Results/Recommendations	Current Status
Wyoming Water Planning Program, 1973, Wyoming's groundwater supplies; Cheyenne, Wyoming State Engineer's Office, Wyoming Water Planning Program Report, variously paged.	Wyoming	All	Summary of available groundwater and groundwater sources.	Predictions of aquifer water quantity throughout the state of Wyoming.	N/A
Wyoming Water Planning Program, 1974, Groundwater potential of the Arikaree Formation in the Sweetwater drainage (Fremont, Natrona, and Carbon Counties, Wyoming); Cheyenne, Wyoming State Engineer's Office, Wyoming Water Planning Program Report, variously paged.	Fremont Natrona Carbon Counties	Arikaree	Reconnaissance investigation of the State's groundwater resources in the Arikaree formation near the Split Rock area.	Large volumes of water removed from the aquifer could alter the Sweetwater River.	N/A
Crist, M.A., 1975, Hydrologic analysis of the valley-fill aquifer, North Platte River valley, Goshen County, Wyoming; U.S. Geological Survey Water-Resources Investigations Report 75-3, 60 p., 4 pls.	Goshen County	Ogallala, Arikaree, Brule, Chadron, Lance Formations	Quantitative evaluation of groundwater in the valley fill, and surface water in the North Platte River Valley.	Contains estimates of the amount of groundwater resources	N/A
Anderson and Kelly, Inc., 1982, Hydrogeologic evaluation of the Casper aquifer (drilling program number 1) Albany County, Wyoming; prepared for the Wyoming Water Development Commission, variously paged.	Albany County	Casper Aquifer	Hydrologic Evaluation; Drilling of exploratory wells, pump testing production, analysis of pump testing data and water quality	Formation has good aquifer potential; water quality degrades toward Cretaceous rocks. Future development from the test location is limited to stock water.	N/A
Black & Veatch, 1982, Hanna, Wyoming, Wyoming Water Development Commission ground water exploration program progress report; prepared for the Wyoming Water Development Commission, variously paged.	Town of Hanna	North Park, Frontier Formations	Examination of possible sources to meet the increasing industrial demand, and investigations of drought constraints on current supply.	Further study is recommended concerning surface water supply for future water demand. Water produced from test wells does not meet EPA water quality standards.	Alternatives of drilling wells for increased water supply was not recommended as well use would likely result in aquifer mining and will not provide a long term solution.
Black and Veatch, 1983, Hanna, Wyoming groundwater exploration program, Wyoming Water Development Commission exploratory drilling report; prepared for the Wyoming Water Development Commission, variously paged.					
Black and Veatch, 1984, Hanna, Wyoming report on water resource development alternatives; prepared for the Wyoming Water Development Commission, variously paged.					
Howard Needles Tammen & Bergendoff, 1982a, Level II feasibility study, water supply for Town of Encampment, phase 1 status report; evaluate existing water supply; prepared for the Wyoming Water Development Commission, variously paged.	Town of Encampment	North Park Formation	Phase I and II status report to evaluate the existing water supply to the town of Encampment	A well field located north of town could supply water to meet the needs of the town of Encampment producing 59 million gallons over a 92 day period. Radionuclides exceed levels allowed by drinking water standards.	Investigation into the feasibility of alternatives based on low capacity and radionuclide problems.
Howard Needles Tammen & Bergendoff, 1982b, level II feasibility study, water supply for Town of Encampment, phase 2 status report, identify and prioritize additional water supply alternatives; prepared for the Wyoming Water Development Commission, variously paged.					

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Citation(s)	Location	Aquifer/ Formation	Project Description	Results/Recommendations	Current Status
Howard, Needles, Tammen, and Bergendoff, 1984, in association with Simons, Li, and Associates, Inc., Water supply for Town of Encampment final report, level II feasibility study; prepared for the Wyoming Water Development Commission, variously paged.					
James M. Montgomery, Consulting Engineers, Inc., 1982a, in association with Anderson and Kelly, City of Rawlins, Wyoming hydrogeologic and water supply study task report No. 1, phase I; prepared for the Wyoming Water Development Commission, 13 p., 1 pl.	City of Rawlins	North Park, Battle Spring, Fort Union, Lance, Mesaverde, Frontier, Cloverly, Tensleep, Madison Formations and Cambrian System	Task Report No. 1, Phase I, is to identify ground water source areas near Rawlins where further evaluation is needed and to eliminate source areas with little or no development potential.	Lance, Fort Union, and Battle Spring Formations are recommended for further evaluation based on quantity and quality of water. The Madison Formation may be cost prohibitive unless production exceeded 500-1,000 gpm.	Recharge to the Battle Spring Formation is meteoric, which may limit recharge. Further study of the area is recommended.
James M. Montgomery, Consulting Engineers, Inc., 1982b, City of Rawlins, Wyoming hydrogeologic and water supply study task report No. 2, phase II, III, IV; prepared for the Wyoming Water Development Commission, variously paged.	City of Rawlins	North Park, Battle Spring, Cloverly, Tensleep, Madison Formations	Results of Task Report No. 2, Phase II, III, and portions of Phase IV of the hydrogeologic water supply study for Rawlins. An evaluation of potential sources of groundwater in the Rawlins area.	Ranked in order of development potential are the Paleozoic formations, North Park Formation, Battle Spring Formation, and the Cloverly Formation.	Experimental test drilling of the Paleozoic sediments underlying the Sage Creek Basin is considered to be warranted.
MSM Consultants, 1982, in association with Willard Owens Associates, Inc., Town of Evansville groundwater availability study, vicinity of Evansville, Wyoming; prepared for the Wyoming Water Development Commission, variously paged.	Natrona County	Cloverly Formation Casper aquifer Madison aquifer	Investigate possible solutions to satisfy future increased water demands through groundwater for the town of Evansville. Develop test wells and relate the results to future water needs.	Groundwater is considered the only new source of potable water. Test wells yield 100-300 gpm with higher yield possible. Total dissolved solid concentration remain under 500 mg/L.	Further testing of the Cloverly Formation for higher yield and better water quality.
Nelson Engineering, 1982. A plan to drill and test a water well south of the Town of Glenrock, Wyoming; prepared for the Wyoming Water Development Commission and the Town of Glenrock, variously paged.	Town of Glenrock	Deer Creek Alluvium Casper Formation	Investigate groundwater sources to increase the town of Glenrock's available water supply during peak demand.	Identified locations for wells to be drilled into the Casper formation.	Proceed with drilling and testing program for wells at the identified locations.
Simons, Li, and Associates, 1982a, Riverside groundwater resources investigation and development, final report; prepared for the Wyoming Water Development Commission, variously paged.	Town of Riverside	North Park Formation	A groundwater resources investigation and development report for the town of Riverside. Collection of information on local major aquifers and development of a potable groundwater supply.	The gravel, sand, and clay are discontinuous through the exploration zone. Water quality corresponds with rock type. Depth to the Precambrian boundary is highly variable with water levels dependent on fractures and faulting.	N/A
Simons, Li, and Associates, 1982b, Riverside groundwater resources investigation and development, interim report; prepared for the Wyoming Water Development Commission, variously paged.					
Western Water Consultants, Inc., 1982, Ground water development potential of the Paleozoic aquifer along the flanks of the Laramie Range and Hartville Uplift, southeastern Wyoming; prepared for the Wyoming Water Development Commission, 88 p., 8 pl.	Laramie County	Paleozoic aquifer	Reconnaissance level evaluation of potential groundwater development from the Paleozoic rocks surrounding the Laramie Mountain-Casper Mountain ranges and Hartville Uplift.	Best quality and quantity of groundwater was found in the Casper/Tensleep and Madison formations.	N/A

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Citation(s)	Location	Aquifer/ Formation	Project Description	Results/Recommendations	Current Status
Banner Associates, Inc., 1983, Feasibility study for groundwater development for the Town of Medicine Bow, prepared for the Wyoming Water Development Commission, variously pagged.	Town of Medicine Bow	Casper aquifer	Determine sources for water to sustain increased future demand.	Shut down Como #3 Well due to contamination in the upper most sand of the aquifer.	Investigate water treatment, develop a new source, improve Como well #3, and construct a new deeper well at same location.
Black & Veatch, 1983, Water Supply Needs Assessment for the North Platte and Little Snake River Drainages Phase I, Vols. 1,2; prepared for the Wyoming Water Development Commission, variously pagged.	North Platte and Little Snake River Drainages	N/A	Phase I, Volumes I & II, analysis of the water supply needs of various communities located within the North Platte and Little Snake River Conservation District.	There is the possibility to develop enough water to meet both in basin and out of basin needs for the near future Analysis.	Continue with Phase II of the Water Supply Needs Analysis.
Hydro-Search, Inc., 1983, Bairoil, Wyoming Groundwater Development Feasibility Exploration Program Design: prepared for the Wyoming Water Development Commission, variously pagged.	Town of Bairoil	Quaternary Alluvium Fox Hills, Lance, Fort Union, and Battle Spring Aquifers	Determine feasibility of groundwater development to supplement current and future demand for the town of Bairoil.	Lance and Fox Hills aquifers are not feasible due to limited saturated thickness and/or low permeability. Battle Spring and Fort Union aquifers are capable of supplying adequate amounts, Battle Spring aquifer is considered to be the more viable source.	Adequate groundwater sources exist in the vicinity of Bairoil for municipal development, an exploration program is recommended.
James M. Montgomery, Consulting Engineers, Inc., 1983a, City of Rawlins water development master plan; prepared for the Wyoming Water Development Commission, 2 v., variously pagged. James M. Montgomery, Consulting Engineers, Inc., 1983b, in association with Anderson and Kelly, Inc., Section I, City of Rawlins hydrogeologic investigations for water supply development final report, in James M. Montgomery, Consulting Engineers, 1983, City of Rawlins water development master plan volume II, background data and reports; prepared for the Wyoming Water Development Commission, variously pagged.	City of Rawlins	North Park, Battle Spring, Cloverly, Nugget and Tensleep Formations	Water Development Master Plan V. I and II, for evaluating sources of water to supplement current water supply for the town of Rawlins.	Cloverly formation has the greatest potential for water development. With 100-150 gpm yields of good water quality. Nugget wells are also producing groundwater in adequate supplies and quality. Remaining aquifers do not have the necessary characteristics for production scale water levels.	Moving forward with drilling and testing of production scale wells.
No author, 1983, Municipal Water Supply Source Problems, Town of Medicine Bow, Wyoming; prepared for the Wyoming Water Development Commission, variously pagged.	Town of Medicine Bow	N/A	Feasibility study to determine most usable option to correct the town of Medicine Bow's water quality issues.	Drill and test a small diameter monitor well. Drill and test a production sized well according to Banner Associates original design. Drill and test production sized well incorporating University of Wyoming design.	N/A
Morrison-Maierle, Inc., 1984a, Casper aquifer drilling program No. 2 with results of aquifer tests, final report: prepared for the Wyoming Water Development Commission, variously pagged.	Converse County	Casper and Madison Aquifers	Level II feasibility study to develop information on the productivity of the Casper Aquifer system.	Wells drilled into the Casper Aquifer yielded water from zones of secondary fracture and encountered artesian pressure at the Casper-Madison contact. Pump test resulted in 104 gpm pumping rates. Transmissivity of 38,098 gpd/ft and storativity of 0.037.	N/A

Appendix B WWDC Groundwater Studies

Citation(s)	Location	Aquifer/ Formation	Project Description	Results/Recommendations	Current Status
Anderson and Kelly, Inc., 1984, Hydrogeologic evaluation of the Nugget aquifer near Rawlins, Wyoming level II feasibility study; prepared for the Wyoming Water Development Commission, variously paged.	Carbon County	Nugget Aquifer	Hydrologic evaluation of aquifer feasibility for supplemental water supply for Rawlins municipal supply	Well could yield 1.5 million gpd, water quality does not meet EPA standards for TDS.	Recommendation for development of Nugget Sandstone for municipal supply
Banner Associates, Inc., 1984, Construction and testing of the Como No. 4 well; prepared for the Town of Medicine Bow and the Wyoming Water Development Commission, variously paged.	Town of Medicine Bow	Casper Aquifer	Drilling and testing phase of the Como #4 Well to replace the Como #3 Well due to radioactive contamination.	Como #4 Well water quality and pump rates were found to be satisfactory. The water producing zone between 580 and 660 feet has high levels of radium present in samples.	N/A
Black & Veatch, 1984, in association with Wright Water Engineers Inc., Water supply needs assessment for the North Platte and Little Snake River drainages Phase II; prepared for the North Platte Water Development Joint Powers Board, variously paged.	Platte and Little Snake River drainages	Various aquifers and surface water	Phase II, Analysis of the municipal, agricultural, and industrial water supply needs within the North Platte and Little Snake River drainages. Investigate the ability of the water users to pay for additional water supplies.	There is a need for additional municipal water supplies in both the North Platte and the Little Snake River Basins; however the amount varies greatly based on water supply assumptions.	N/A
Morrison-Maierle, Inc., 1984b, Glendo groundwater exploration program feasibility study; prepared for the Wyoming Water Development Commission and the Town of Glendo, variously paged.	Town of Glendo	Hartville Formation	Exploration program to determine supply needs for current and future water demands for the town of Glendo.	The current system is capable of providing supply for peak summer consumption. Future needs cannot be met by this rate of extraction.	Replace transmission line with a larger capacity line or provide adequate storage for peak use times.
James M. Montgomery, Consulting Engineers, Inc., 1986b, Rawlins groundwater project level III, Nugget Aquifer report; prepared for the Wyoming Water Development Commission, variously paged.	City of Rawlins	Cloverly and Nugget Formations	Level III Interim/Summary Report to aid in a detailed evaluation of improvements to the city of Rawlins existing water supply.	Wells in the Nugget Sandstone exceeded minimum secondary standards for TDS and sodium concentration. Shut in, the well maintains a 140 psi pressure and a discharge of 350 gpm.	Implement plans and findings of Level III report. Limit storage requirements, maintain groundwater supply, reduce use of existing North Platte water supply, and properly size Sage Creek Water transmission line.
James M. Montgomery, Consulting Engineers, Inc., 1986a, Rawlins groundwater project level III, interim report: prepared for the Wyoming Water Development Commission, variously paged.	City of Rawlins	Nugget Aquifer	Rawlins Groundwater Project Level III, Nugget aquifer report gives detail for recovery rates of the test wells into the Nugget Sandstone and details need for future wells to meet future demand.	Nugget Wells No. 2 and 3 drilled to depths of 1,743 and 1,625 ft respectively with short-term flows of 900 and 80 gpm. Long-term recovery tests show flows of 650 and 80 gpm respectively. Long-term flow was increased from 80 gpm to 400 gpm after hydraulic fracturing of Well 3.	Examination of further well sites at three identified locations is recommended to increase maximum flow rates. Also recommends hydrologic fracturing to increase the flow rate in any new wells.
Nelson Engineering, 1986, Glenrock water supply design report; prepared for the Town of Glenrock and the Wyoming Water Development Commission, variously paged.	Town of Glenrock	Casper Aquifer	Report contains an operating plan for new water supplies, conceptual design for facilities, and a summary of findings from hydrological investigations for the town of Glenrock.	Well design capacity should be at least 600 gpm. Water quality is similar to that of neighboring wells. No reduction of stream flow was observed during pumping of the well.	Project was determined to be feasible and suitable.

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Citation(s)	Location	Aquifer/Formation	Project Description	Results/Recommendations	Current Status
Wyoming Water Development Commission, 1986, Casper aquifer exploration program summary report: Cheyenne, Wyoming Water Development Commission, 13 p.	Southeast Wyoming	Casper Aquifer	Program report to determine the quality, quantity, and availability of water within the Casper aquifer.	Areas tested show high capacity and good quality water in the aquifer within a relatively short distance from the recharge area, and also where permeability has been enhanced due to deformation or solution activity.	A more detailed description of the results can be found in individual reports.
Anderson and Kelly, Inc., 1987, Hydrogeologic evaluation of the Natural Bridge well, Converse County. Wyoming: prepared for ARIX Corporation, variously paged.	Converse County	Casper aquifer	Evaluate well potential maximum pumping and usage rates	Total available drawdown of 129 feet which will occur in 9.8 years with continuous use.	Recommendation for non-continuous usage to alleviate potential for maximum drawdown
Centennial Engineering & Research, Inc., 1989, Ridgeway Water Supply Project Level II, Phase I Report: prepared for the Wyoming Water Development Commission, variously paged. Centennial Engineering and Research, Inc., 1991, Ridgeway water supply project level II, final report: prepared for the Wyoming Water Development Commission, variously paged.	Converse County	White River Formation	Level II, Phase I and Final Report evaluation of groundwater supply and quality from an exploratory well for the City of Douglas and Ridgeway Improvement and Service District.	The city of Douglas would own, operate, and maintain the 1,200 gpm of treated water distributing it to the city and the Ridgeway District. This water supply would be sufficient to service rural users.	All water issues should be dealt with according to the signed agreement between the two parties.
James M. Montgomery, Consulting Engineers, Inc., 1989, Centennial water supply project report: prepared for the Wyoming Water Development Commission and the Centennial Water and Sewer District, variously paged.	Albany County	Casper Formation	Centennial Water Supply Project and Executive Summary was commissioned to determine water supply sources for the community of Centennial.	Based on all necessary criteria, bedrock groundwater is the most suitable source to expand the current water supply. Long term yield of 40 gpm, high water quality, and no conflicting water use.	Provided that funding can be secured, construction based on the design within the report should be carried out.
James M. Montgomery, Consulting Engineers, Inc., 1990b, Natrona County regional water system project level I: prepared for the Wyoming Water Development Commission, variously paged.	Natrona County	Casper aquifer Madison aquifer	The Evansville Groundwater Supply Project Final Report was commissioned in an attempt to determine if groundwater is a viable source for the municipal water supply.	The current water supply needs of the town of Evansville are adequate for the estimated population for 50 years.	Concerns for future water supply revolve around prior appropriation of currently used surface water. If surface water rights are claimed, groundwater will provide a more secure source.
James M. Montgomery, Consulting Engineers, Inc., 1990c, Report of drilling and testing Rolling Hills well No. 5: prepared for the Wyoming Water Development Commission and the Town of Rolling Hills, variously paged.	Converse County	Fort Union/Lance aquifer	Drilling and testing report for the Rolling Hills No. 5 well summarizes findings from afore mentioned well. Groundwater supplies from previous wells were no longer sufficient and further resources are needed.	Development potential of the aquifer is most likely deeper in the formation as the sands are more laterally continuous. Water from the well meets all EPA standards for primary water. Production capacity of 96 gpm was projected.	Completion of the Level II report

Appendix B WWDC Groundwater Studies

Citation(s)	Location	Aquifer/Formation	Project Description	Results/Recommendations	Current Status
PMPC, 1990, Level II analysis Riverside area municipal water supply system. Town of Riverside, Carbon County, Wyoming, interim report: prepared for the Wyoming Water Development Commission, variously paged.	Carbon County	North Park Formation	Determine the feasibility of creating a municipal water supply system from the existing individual owner-wells for the town of Riverside.	A well field consisting of a minimum of three wells with the possibility to add more.	Recommended to go ahead with the formation of a municipal water system.
PMPC, 1992, Level II analysis Riverside municipal water supply system, Town of Riverside, Carbon County, Wyoming, volume I, final report and volume II, technical appendix: prepared for the Wyoming Water Development Commission, variously paged.					
States West Water Resources Corporation, 1990, in association with ESA Consultants, Crow Creek groundwater recharge project, level II: prepared for the Wyoming Water Development Commission, variously paged.	Laramie County	Alluvial deposits Terrace deposits Ogallala Formation White River Formation	Phase IB of Level II feasibility evaluation of the Crow Creek flood control and groundwater recharge project. Examining recharge of the groundwater system in the Carpenter Wyoming area.	Conditions are favorable for the implementation of an experimental groundwater recharge in the vicinity of Carpenter.	N/A
TriHydro Corporation, 1990b, Ridgewater water supply project level II, phase II report: prepared for Centennial Engineering and Research and the Wyoming Water Development Commission, variously paged.	Converse County	Casper Formation	Level II, Phase II study to determine the feasibility of developing groundwater in sufficient quantity and quality to meet future domestic and fire-protection requirements of Ridgewater.	Groundwater quality is of acceptable quality for municipal use. Maximum pump rate of 1,039 gpm. Seven day pumping average of 1,001 gpm. Conductivity of 1,715 gpd/ft ² , and a transmissivity of 574,660 gpd/ft.	N/A
TriHydro Corporation, 1990a, Construction and testing report Yoder No. 2 production well, Yoder, Wyoming: prepared for Wells Engineering, variously paged.	Goshen County	Brule Formation	Exploration phase to increase the quality and quantity of water to satisfy the water requirements of the town of Yoder, Wyoming	Based on aquifer parameters, it is recommended that a groundwater management plan including a well field be implemented to meet the demands of the town of Yoder	N/A
Coffey Engineering and Surveying, Inc., 1991, in association with James M. Montgomery, Consulting Engineers, Ryan Park water supply project final report, water supply alternatives level I: prepared for the Wyoming Water Development Commission, variously paged.	Carbon County	Quaternary Alluvium Tertiary Alluvium Precambrian	Development of a conceptual design for a water supply system of the unincorporated community of Ryan Park.	Four sites have been identified for further studies of groundwater exploration or development. The Barrett Creek Site was identified after consultation with WWDC and location owner. The Ryan Park Deep Well Site was also identified as a possibility.	Formation of an official district and proceed with a level II study
Snowy Range Water Consultants, Inc., 1991, South Laramie water supply project level I, final report: prepared for the Wyoming Water Development Commission, variously paged.	Albany County	Casper aquifer	Evaluate the potential for providing potable water to the South Laramie vicinity in Albany County.	Construction of two wells a mile apart along the Laramie fault that can be readily incorporated into the city system at a later date.	N/A
States West Water Resources Corporation, 1991, Upper Laramie River basin planning study, level I investigation: prepared for the Wyoming Water Development Commission, variously paged.	Albany County	Tertiary aquifer Cloverly aquifer Casper-Tensleep aquifer	Level I planning study, evaluation of alternatives for supplying late-season irrigation water to the Irrigation district, and reduction of reservoir storage losses for the Pioneer Canal-Lake Hattie district.	Alternatives to the current water use program do not include the utilization of ground water.	Move forward with a Level II study

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Citation(s)	Location	Aquifer/ Formation	Project Description	Results/Recommendations	Current Status
James M. Montgomery, Consulting Engineers, Inc., 1992, Centennial water supply project report, 1990 Centennial wells No. 1 and 2 aquifer testing; prepared for the Wyoming Water Development Commission and the Centennial Water and Sewer District, variously paged.	Albany County	Casper aquifer	Aquifer testing for wells No. 1 and 2 for the Centennial water supply project.	Development from the Casper aquifer does not affect nearby surface water. Pumping rates in wells exceeded 150 gpm. Water quality from both wells is within criteria set for primary and secondary EPA standards	N/A
States West Water Resources Corporation, 1996, in association with Chugwater Enterprises, and West-Weinstein and Associates, Inc., Town of Chugwater water supply master plan level I project; prepared for the Wyoming Water Development Commission, variously paged.	Platte County	Tertiary aquifer	Level I reconnaissance investigation to develop a water supply master plan for the North Cheyenne area.	Development has affected the chemical quality of water in North Cheyenne, no sample exceeded EPA standards. However, the proposed EPA standard for radon was exceeded in three of the four wells sampled. A distribution system with a water supply from the city of Cheyenne is recommended.	N/A
AVI Professional Corporation, 1994, Pine Bluffs level I water study; prepared for the Wyoming Water Development Commission, variously paged.	Laramie County	Brule Formation	Evaluate existing water supply to determine any deficiencies for the town of Pine Bluffs.	Static water levels in existing wells have dropped and average of 4 feet in 15 years. Ground water may be under influence from surface contamination.	Production capacity must be tested with long term constant discharge testing.
Baker and Associates, 1994, Wellhead protection program, Torrington, Wyoming; chapter III ground water investigation monitoring wells and chapter IV ground water monitoring results; prepared for the Wyoming Water Development Commission, variously paged.	Goshen County	Brule Formation	Determine the source of nitrate contamination in the municipal water supply of Torrington.	Nitrate contamination comes dominantly from agricultural and urban fertilization, feedlot, and chemical storage sources.	Relocation of wells to less contaminated areas and management programs limiting nitrate entering groundwater systems.
Black and Veatch, 1994, in association with Western Water Consultants, and West-Weinstein and Associates, Cheyenne water supply master plan level I; prepared for the Wyoming Water Development Commission and the Cheyenne Board of Public Utilities, 3 v., variously paged.	Laramie County	Casper Formation	Assist the Cheyenne Board of Public Utilities in developing strategies concerning future water supply, treatment, and distribution systems.	Groundwater supplies are sustainable at a pumping rate of 5,500 acre-feet per year, which is the limit imposed by the State Engineers Office.	The Casper Formation offers the opportunity to develop additional groundwater in the vicinity of the existing facilities. Recommendation for exploration programs in target areas.
PMPC, 1994, Level II analysis Ryan Park water supply project Ryan Park, Carbon County, Wyoming, final report; prepared for the Wyoming Water Development Commission, variously paged.	Carbon County	North Park Formation Precambrian	Determine an adequate source for the recommended community water supply system in Ryan Park.	Recommend drilling wells to meet the demand of 72 gpm.	N/A
Worthington, Lenhart, and Carpenter, 1994, Town of Lusk water project level I master plan study, final report; prepared for the Wyoming Water Development Commission, variously paged.	Niobrara County	Arikaree aquifer	Level I study to determine future water needs relative to current supplies for the municipal water supply district of Lusk.	Drilling of an additional well will satisfy demand until 2020.	N/A

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Citation(s)	Location	Aquifer/ Formation	Project Description	Results/Recommendations	Current Status
Cofley & Associates, 1995, Corner Mountain water supply project, water supply alternatives, level I, final report; prepared for the Wyoming Water Development Commission, variously pagged.	Albany County	Cloverly Formation Casper Formation	Level I feasibility study for a conceptual design of water supply for the Corner Mountain area.	Deep water wells are expected to fill the current and future needs of the land owners. Cloverly Formation wells are expected to yield 50-100 gpm. Casper Formation sites are expected to yield 30-50 gpm.	Recommendation for the formation of a water district. Landowners need to compare the cost of drilling a well and continued maintenance versus the fees associated with joining a water district.
Lidstone and Anderson, 1995, in association with A VI, P C., Final report, Town of Pine Bluffs water supply project level II; prepared for the Wyoming Water Development Commission, variously pagged.	Laramie County	Brule aquifer	Level II study to determine cause of declining water production for the town of Pine Bluffs, define characteristics of aquifer used, and meet demand and legal requirements with increased production.	Projected drawdown after 20 years of pumping from the field showed a maximum of 2 feet in the center to 1.5 feet at the nearest irrigation well. This drawdown shows sufficient supply for current and future needs.	N/A
MK Centennial, 1995, Lusk water supply project level II Lusk, Wyoming, final report; prepared for the Wyoming Water Development Commission, variously pagged.	Niobrara County	Arikaree Formation	Construct an additional water supply well and prepare conceptual designs and cost estimates for improvements to the existing system.	The predominantly sandstone with coarse basal conglomerate of the Arikaree Formation yielded 1,000 gpm during pump tests.	Final well development was completed at the end of this phase.
TST Inc., 1995a, in association with Rio Verde Engineering, and Weston Engineering, Guernsey water supply master plan, level I final; prepared for the Wyoming Water Development Commission, variously pagged.	Platte County	Quaternary Sediments Tertiary Sediments Hartville Formation Darwin Sandstone Madison Formation Freemont Canyon Sandstone Precambrian	Determine the condition, storage, transmission, and remaining useful life of the water supply and distribution system for the town of Guernsey.	Production of 550 and 1,000 gpm pumping rates for current wells. Recommended that the town complete a fourth well to replace inefficient wells. Concentration of iron and manganese exceed the secondary water standards. Groundwater potential from Paleozoic rocks in the area is poor.	N/A
Weston Engineering, Inc., 1995a, Elk Mountain water supply master plan, level I report; prepared for the Wyoming Water Development Commission and the Town of Elk Mountain, variously pagged.	Carbon County	Dakota Sandstone Lakota Sandstone	Level I and II reports for the town of Elk Mountain water district to evaluate the current water distribution facilities and needs.	Construction of a new well into the currently used aquifer to produce the necessary water to supply municipal needs.	N/A
Weston Engineering, Inc., 1995b, Elk Mountain water supply project, level II final report; prepared for the Wyoming Water Development Commission and the Town of Elk Mountain, variously pagged.					
BRS Inc., 1996, in association with Lidstone and Anderson, Inc., Hawk Springs water supply project, final report; prepared for the Wyoming Water Development Commission, variously pagged.	Goshen County	Arikaree Formation Lance Formation	Determine the feasibility of creating a community water and waste water treatment system.	The Lance Formation in the area is not suitable for drinking water.	The district must be able to provide service to at least 30 to 35 taps for the project to be feasible.

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Citation(s)	Location	Aquifer/ Formation	Project Description	Results/Recommendations	Current Status
States West Water Resources Corporation, 1996, in association with Chugwater Enterprises, and West-Weinstein and Associates, Inc., Town of Chugwater water supply master plan level I project; prepared for the Wyoming Water Development Commission, variously paged.	Platte County	Brule Formation	Level I reconnaissance investigation to develop a water supply master plan for the town of Chugwater.	Proposed locations of two new wells into the existing aquifer, located in either the current well field or next to the storage tank. Flow rate of 157 gpm, static water level of 34.15 feet	Proceed with Level II study.
TriHydro Corporation, 1996, Well construction and aquifer testing level II water supply project, Lusk Wyoming, final report; prepared for the Wyoming Water Development Commission and Centennial Civil Engineers, Inc., variously paged.	Niobrara County	Arikaree Formation	Level II study to determine new sources of groundwater to replace outdated and degrading water supplies and systems for the town of Lusk.	A minimum of four wells with average production rates of 819 gpm would be needed to supply future demands for the town of Lusk, Wyoming.	N/A
TriHydro Corporation, 1996, Level II water supply project, Rolling Hills, Wyoming, final report; prepared for the Wyoming Water Development Commission and the Town of Rolling Hills, variously paged.	Converse County	Fort Union Formation Lance Formation	Level II project to evaluate the feasibility of increasing the supply to the town of Rolling Hills, Wyoming.	Water quantity and quality from the Lance Formation is within the limits and requirements. Aquifer mining is a concern.	Install and test the Rolling Hills No. 6 well to evaluate the feasibility of increasing the water supply.
PMPC, 1997, Final report, level II feasibility study, Encampment water supply system; prepared for the Wyoming Water Development Commission, variously paged.	Carbon County	North Park Formation	Level II feasibility study for the town of Encampment's community water supply system.	The town has the sufficient rights to acquire all water needed from the North Fork Encampment River.	N/A
Western Water Consultants, 1997, Final report on the Manville water supply project level II, Volumes I and II; prepared for the Wyoming Water Development Commission, variously paged.	Niobrara County	Arikaree aquifer	Level II project to evaluate the groundwater supply and existing wells for the town of Manville.	Groundwater quality from the aquifer is considered excellent and is the best source of water for the municipality.	Proceed with completion of required aspects of the WHP plan and preparing a contingency plan.
Western Water Consultants, Inc., 1997, in association with Richard P. Arber Associates, City of Rawlins water supply project level II, phase I report; prepared for the Wyoming Water Development Commission, variously paged.	Carbon County	Nugget Sandstone	Level II water supply project of the water supply system for the town of Rawlins.	A current supply deficit will be made up using supply from the North Platte River surface water source.	Plan to improve delivery from the surface water source.
Western Water Consultants, Inc., 1998, in association with Richard P. Arber Associates, City of Rawlins water supply project level II, phase II report; prepared for the Wyoming Water Development Commission, variously paged.	Goshen County	Quaternary Alluvium	Investigation into development of a water supply plan for the town of Lingle.	The current storage and supply network for the town of Lingle sufficient to support growth for the foreseeable future.	N/A
Benchmark of Torrington, P.C., 1998, Town of Lingle water supply master plan level I project, final report; prepared for the Wyoming Water Development Commission, variously paged.	Laramie County	Ogallala Formation White River Group Lance Formation Fox Hills Sandstone	Test drilling program to investigate the geology, hydraulic properties, and water quality at three locations in the Cheyenne area.	Costs an expected to exceed other water supply options in the Cheyenne area. Continued rehabilitation of wells should occur in the Happy Jack Well Field as they have a potential for applications.	N/A

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Citation(s)	Location	Aquifer/ Formation	Project Description	Results/Recommendations	Current Status
Coffey & Associates, 1998, in association with Banner & Associates, Inc., Nine Mile water supply project level I, final report; prepared for the Wyoming Water Development Commission, variously paged. Western Water Consultants, 1999, Report of the level II study for the Nine Mile Water and Sewer District; prepared for the Wyoming Water Development Commission, variously paged.	Albany County	Quaternary Alluvium Frontier Formation Cloverly Formation Casper Formation	Level I and II studies exploring alternatives to the current method of water acquisitions for residents in the Nine Mile development west of Laramie.	Water within the shallow unconfined aquifer is not acceptable as a potable water source. Water has a higher than adequate TDS and sulfate concentration. Suitable water can be obtained from deeper, confined aquifers.	Via options for water supply is from the municipal water supply from the city of Laramie.
Sear-Brown Group, 1998, City of Douglas Water System Master Plan Level I; prepared for the Wyoming Water Development Commission, variously paged.	Converse County	Casper Formation	A Level I Water System master Plan to evaluate and provide recommendations concerning the town of Douglas's raw water supply.	Replacement of existing facilities should be evaluated.	N/A
Sunrise Engineering and Weston Engineering, Inc., 1998, Glenrock raw water irrigation project level II study, phase I; prepared for the Wyoming Water Development Commission, variously paged. Sunrise Engineering and Weston Engineering, Inc., 2000, Glenrock water source project level II study, phase II, final report; prepared for the Wyoming Water Development Commission, variously paged.	Converse County	Casper Formation Madison Limestone Flathead Sandstone	Level II water supply study for the town of Glenrock. Test well drilling, field evaluation, and modeling of the distribution system.	Maximum pump rate of 1,200 gpm with both the Casper and Madison Formations being utilized. Water quality does not exceed any DEQ standards.	N/A
Civil Engineering Professionals, Inc., 1999, in association with West Plains Engineering and Weston Engineering, Final Report, Douglas water supply rehabilitation project level II study; prepared for the Wyoming Water Development Commission, variously paged.	Converse County	Quaternary Alluvium	Determine if the groundwater supply is influenced from surface waters in a zone of current and future development.	Spring flow experiences seasonal flow variation which coincides with spring snow melt. ¹⁴ C samples indicated that the water from the spring is ~1,620 years old. Conclusions are that the ground water is not under direct influence from surface water.	Complete source water protection plan was recommended by the report authors.
Coffey & Associates, 1999, in association with Weston Engineering, Corner Mountain water supply project level II, final report; prepared for the Wyoming Water Development Commission, variously paged. Coffey & Associates, 2001, in association with Weston Engineering, Corner Mountain Water Supply Project Level II, Phase III; prepared for the Wyoming Water Development Commission, variously paged.	Albany County	Cloverly Formation Casper Formation	Level II feasibility study for a conceptual design for water supply for the Corner Mountain area water users.	Target aquifers were not encountered during drilling but logging identified several possible water-bearing strata. Further testing of the Cloverly Formation is recommended, cost is within range of user finance.	N/A
Lidstone and Associates, Inc., 2000, Bairoil water supply project level II, final report; prepared for the Wyoming Water Development Commission, variously paged. Lidstone and Associates, Inc., 2001, Bairoil water supply project level II, phase IV, final report; prepared for the Wyoming Water Development Commission, variously paged.	Sweetwater County	Battle Spring aquifer Fort Union Formation	Level II study to evaluate the current system and make recommendations for the development of a long term reliable water supply source for the municipality of Bairoil.	Alternative groundwater supplies are two from the Quaternary alluvium or colluviums aquifer and two alternatives would utilize a deep Tertiary groundwater source in the Fort Union Formation.	Utilization of the Battle Spring aquifer well is recommended.

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Citation(s)	Location	Aquifer/Formation	Project Description	Results/Recommendations	Current Status
Lidstone and Associates, Inc., 2003, Town of Bairoil water supply project level II, phase V report: prepared for the Wyoming Water Development Commission, variously paged.	Laramie County	White River Formation	Feasibility of aquifer storage and retrieval technologies in the Lodgepole Creek Basin.	Quaternary materials and alluvium appear to provide a medium for recharge. Water from Chivington and Durham well fields would be compatible with current aquifer water.	The ASR project is not feasible at this time due to the cost of water supply and transmission.
Dahlgren Consulting, Inc., 2001, in association with Natural Resources Consulting Engineers, Hydrokinetics and ECI, Lodgepole Aquifer storage and retrieval level I study, final report: prepared for the Wyoming Water Development Commission, variously paged.	Laramie County	White River Formation	Feasibility of aquifer storage and retrieval technologies in the Lodgepole Creek Basin.	Quaternary materials and alluvium appear to provide a medium for recharge. Water from Chivington and Durham well fields would be compatible with current aquifer water.	The ASR project is not feasible at this time due to the cost of water supply and transmission.
Banner Associates, Inc., 2002, Powder River water supply level I study: prepared for the Wyoming Water Development Commission, variously paged.	Natrona County	Quaternary Alluvium Frontier Formation Cloverly Formation	Identify water treatment options available to residents and/or develop an alternate water source for residents of Powder River.	Install centralized or point-of-use reverse osmosis treatment systems, locate a new source of supply.	A five mile radius of economic feasibility was determined for future wells. Samples were collected in an attempt to correlate geology.
CEPI, 2002, South Garden Creek water supply level I study: prepared for the Wyoming Water Development Commission, the Central Wyoming Regional Water System and the City of Casper, variously paged.	Natrona County	Quaternary Alluvium Lakota Sandstone	Evaluate methods of providing public water supplies to serve the developments within the study area to supplement groundwater.	Supply options were determined for each zone within the South Garden Creek area of Casper.	N/A
Lidstone and Associates, Inc., 2003, Town of Pine Bluffs ground water exploration grant final report: prepared for the Wyoming Water Development Commission, variously paged.	Laramie County	Brule aquifer Chadron Formation Lance Formation	Final Report to determine a suitable replacement for the towns existing well #5 as it has decreased in production in association with drought.	Two suitable sites were located, both into the Brule aquifer, having 300 and 700 gpm pumping rates. Exploration of the Lance formation resulted in the determination that it would be a suitable aquifer yielding 50-100 gpm.	Recommendation for further exploration of the Lance/Fox Hills test sites with deeper wells.
PMPC, 2003, in association with TST Inc., Hinekley Consulting, and Water Right Services, Saratoga master plan update and level I study, final report: prepared for the Wyoming Water Development Commission, variously paged.	Carbon County	North Park Formation	Level I study evaluating the current system, estimation of future system needs, and groundwater as an alternative for future needs.	Identification of two suggested exploration sites to evaluate the North Park Formation. Water quality is not expected to increase with depth so well(s) should be drilled to the threshold water quality depth.	Pursuit of a Level II groundwater investigation program.
TST Inc., 2003, in association with AVI, Guernsey hydraulic study level II, final report: prepared for the Wyoming Water Development Commission, variously paged.	Platte County	Hartville Formation Madison Formation Precambrian	Level II study evaluating the pending groundwater disinfection rules and the ability of the current system to meet those needs. Determine the condition and remaining useful life of the water supply, storage and transmission system for the town of Guernsey.	All incidences of contamination were reported as isolated incidences, not regular or continued issues. Need for an alternate water supply source closer to point of use. Access to water source is inaccessible during some times of the year and after incidences.	N/A

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Citation(s)	Location	Aquifer/ Formation	Project Description	Results/Recommendations	Current Status
Lidstone and Associates, Inc., 2004, Platte Goshen regional master plan level I study, prepared for the Wyoming Water Development Commission, 93 p.	Platte and Goshen County	Quaternary aquifers Tertiary aquifers Paleozoic aquifers	Investigate the feasibility of developing a regional water supply system for several communities within the two counties to dampen costs of compliance with current EPA standards.	Groundwater alternatives require new well fields at Hartville, Dwyer, Kelly Park, Caber and Wycross prospect locations with storage at Guernsey, Lingle, and Hawk Springs in order to serve all communities within the study area.	N/A
TriHydro Corporation, 2004, in association with Lidstone and Associates, Inc., Task 7 groundwater exploration programs, Split Rock and Shirley Mountains groundwater prospects, North Platte River groundwater assessment study project report: prepared for the Wyoming Water Development Commission, variously paged.	Platte River Basin	Ogallala Formation Arikaree Formation Split Rock Formation White River Formation	Investigation into the available groundwater resources of the North Platte River Basin and adjacent areas of Wyoming. Task 7 details the design of the exploration program.	Aquifer and water quality testing in the vicinity of Split Rock and the Shirley Mountains within the Platte River Basin.	N/A
TriHydro Corporation, 2007, Project report Split Rock groundwater development project phase IV feasibility study for pumping stations and pipeline to Casper: prepared for the Wyoming Water Development Commission, variously paged.					
Benchmark Engineers, P.C., 2005, in association with Dahlgren Consulting, Inc., and WWC Engineering, Town of Albin well and water supply level II: prepared for the Wyoming Water Development Commission, variously paged.	Laramie County	Ogallala aquifer Arikaree aquifer White River aquifer	Evaluate current water supply system and make recommendations for improvements to meet future demand.	New wells should be constructed into the Ogallala aquifer south of Albin.	N/A
Dahlgren Consulting, Inc., 2005, in association with Stockdale Consulting, Inc., SRK Consulting, Inc., Benchmark Engineers, and Greystone, Pine Bluffs Lance/Fox Hills well level II study, final report: prepared for the Wyoming Water Development Commission, variously paged.	Laramie County	Lance Formation Fox Hills Sandstone	Level II study designed to complete wells into the formations and evaluate aquifer characteristics and water quality.	Target flow was reached for all wells with 96% recharge. Water quality was acceptable, but has high sodium, TDS, and pH	Secure funding for and proceed with the Level III study.
JR Engineering, LLC., 2005, Cheyenne Belvoir Ranch level II study, final report: prepared for the Wyoming Water Development Commission, variously paged.	Laramie County	Ogallala aquifer	Determine water sources for further development in the Ogallala aquifer in the Belvoir Ranch area	Data from 7 test wells was used to create cross sections and detailed understanding of the aquifer within the ranch. Wells 1-4 have sufficient saturated thickness; wells 6 and 9 did not meet minimum criteria. Wells are capable of 750-100 gpm pumping rates. Water meets water quality standards locally and nationally.	Monitor test wells and recommendation for drilling more.
Weston Engineering, Inc., 2005, in association with Civil Engineering Professionals, Inc., Glenrock level II well and tank feasibility study, interim report: prepared for the Wyoming Water Development Commission, variously paged.	Converse County	Chugwater Formation Goose Egg Formation Casper Formation Madison Limestone Flathead Sandstone	Investigate any potential impacts to groundwater and surface water sources attributed to pumping from the water supply wells near the town of Glenrock.	No discernible impact was observed at any of the monitoring stations as a result of pumping.	Maximum pump rates of 2,000 gpm. Recommended that all monitoring equipment be removed.
Weston Engineering, Inc., 2006, in association with Civil					

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Citation(s)	Location	Aquifer/Formation	Project Description	Results/Recommendations	Current Status
Engineering Professionals, Inc., Glenrock well and tank project level II feasibility study, water tank and pipeline improvements, interim report; prepared for the Wyoming Water Development Commission, variously pagged. Weston Engineering, Inc., 2007, in association with Civil Engineering Professionals, Inc., Glenrock level II well and tank feasibility study, final report; prepared for the Wyoming Water Development Commission, variously pagged.	Converse County	Chugwater Formation Goose Egg Formation Casper Formation Madison Limestone Flathead Sandstone	Investigate hydrogeology of Glenrock area to determine feasibility of finding a redundant municipal water supply.	Glenrock Test Well No. was completed in the Paleozoic aquifer to a total depth of 1,233 feet below ground surface. The well can provide up to 1500 gpm of good quality water. Glenrock should purchase Glenrock Test Well No. 7 from WWDC and design and construct the necessary water delivery infrastructure to integrate the well into the town's public water system.	
TriHydro Corporation, 2006a, in association with Lidstone and Associates, Harvey Economics, and Water Rights Services, LLC, Platte River Basin plan, final report; prepared for the Wyoming Water Development Commission, variously pagged.	Platte River Basin	Quaternary Tertiary Mesozoic Paleozoic Precambrian	Investigation into the available groundwater resources in the Platte River Basin, Final Report and Technical memorandums.	Summary of water use and availability and future demands for the Platte River Basin. Currently Used aquifer systems are listed.	N/A
WVC Engineering, 2006a, in association with Camp Creek Engineering, Inc., Burns and McDonnell, Wyoming Groundwater, LLC, and Fassett Consulting, LLC., Laramie water management plan level II, volume I of II; prepared for the Wyoming Water Development Commission and the City of Laramie, variously pagged.	Albany County	Casper aquifer	Level II Water System Master plan to address the comprehensive water system needs for the city of Laramie.	Installation of three additional wells with a capacity of 500 gpm	The city should proceed with a Level II study including test well work.
Hinckley Consulting, 2007, in association with PM/PC Civil Engineers, TST Inc., and Wester-Weinstein and Associates, Saratoga test well level II study, final report; prepared for the Wyoming Water Development Commission, variously pagged.	Carbon County	North Park Formation	Preliminary investigation of viable groundwater source to provide sufficient quantities and quality within a 3 mile radius of the town of Saratoga.	The aquifer was found to be within drinking water standards, general behavior was that of an unconfined aquifer with transmissivity of 30,000 gpd/ft and storage coefficient of ~0.05.	Completion of permitting and design work.
JR Engineering, LLC., 2007b, Cheyenne Belvoir Ranch level II study, phase III-V, final report; prepared for the Wyoming Water Development Commission, variously pagged.	Laramie County	High Plains aquifer Ogallala Formation White River Formation	Characterize the present development of the groundwater resources on and around the Cheyenne Belvoir Ranch and determine the potential for future development of water resources. Summary of the Phase III-V of the Level II report.	Recommendation of completion of Test well #5 for municipal water supply. Wells should be drilled into the White River Formation to explore for future water needs.	Use of existing data for exploration of the High Plains and Casper aquifers.
JR Engineering, LLC., 2007a, Belvoir Wells No. 5 and 6 pumping test report, aquifer impact report; prepared for the Wyoming Water Development Commission, variously pagged.	Laramie County	Ogallala aquifer	Report describes the construction and testing of the No. 5 and 6 wells and test holes on the Belvoir Ranch.	Distinct layers of permeability have been identified within the aquifer. Both wells are hydraulically disconnected from the lower portion of the aquifer. The predicted 25 year drawdown in not considered to be significant based on a 550 and 300 gpm pumping rate.	Recommended that the water should be produced from the lower portions of the aquifer as it is disconnected with any potential surface water sources. All current monitoring stations should be continued indefinitely.

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Citation(s)	Location	Aquifer/ Formation	Project Description	Results/Recommendations	Current Status
PMPC, 2007, in association with Hinekley Consulting, Encampment Sierra Madre Well level II study, summary report; prepared for the Wyoming Water Development Commission, Cheyenne, Wyo., variously paged.	Carbon County	North Park Formation	Level II study for the Encampment Sierra Madre well. The study is to investigate the possibility of supplying the town with groundwater.	Water produced is in excess of the current needs, quality is within EPA standards, no evidence for long-term decline in aquifer water levels.	N/A
Trihydro Corporation, 2007b, Project report task 1 through 6 – North Platte River groundwater assessment study southeast Wyoming (revised); Prepared for the Wyoming Water Development Commission, Cheyenne, Wyo., 296 p.	Platte River Basin	Ogallala Formation Arikaree Formation Split Rock Formation White River Formation	Investigation into the available groundwater resources of the North Platte River Basin and adjacent areas of Wyoming. Tasks 1-6.	Top three prospects are the Split Rock, Hartville, and Shirley Mountains. Development of multiple prospects is recommended. Top three prospects may yield over 10,000 acre-feet per year. Based on field investigations the Hartville prospect was not recommended for development.	N/A
WWC Engineering, Inc., and others, 2007a, Wyoming framework water plan; prepared for the Wyoming Water Development Commission, Cheyenne, Wyo., v. 1 and 2, variously paged.	State Wide	All	Wyoming Framework Water Plan, volumes I and II.	Total use of groundwater state wide totals 216,000 acre-feet per year.	N/A
AVI, 2008, in association with Black & Veatch, Dahlgren Consulting, Inc., Short Elliott Hendrickson, Inc., and Stockdale Consulting, Cheyenne/Laramie County water service area level II study volume I, Archer special use district water master plan; prepared for the Wyoming Water Development Commission, Cheyenne, Wyo., variously paged.	Laramie County	High Plains aquifer	Address water supply options and the framework for transmission of the projected development in East Cheyenne area.	Aquifers are capable of supplying sufficient quantities of water to meet projected demand.	Investigate feasibility of alternative to meet projected demands.
AVI, 2008, in association with Black & Veatch and Short Elliott Hendrickson, Inc., Cheyenne/Laramie County water service area level II study volume II, East Cheyenne water master plan; prepared for the Wyoming Water Development Commission, Cheyenne, Wyo., variously paged.	Laramie County	High Plains aquifer	Address water supply options and the framework for transmission of the projected development in East Cheyenne area.	Aquifers are capable of supplying sufficient quantities of water to meet projected demand.	Investigate feasibility of alternative to meet projected demands.
Olsson Associates, 2008, Manville Source Water Supply Study Level II Study, Final Report; prepared for the Wyoming Water Development Commission, Cheyenne, Wyo., 387 p.	Niobrara County	Arikaree Formation	Investigating options to bring the Manville water supply into compliance with the EPA standards for uranium.	A well field one mile north of town would eliminate the uranium contamination problems. Combining water from the new well field with the current would increase supply and decrease uranium concentrations.	Chose the lowest cost alternative, which was to install POU/POE systems.
Trihydro Corporation, 2008a, Hydrologic connection report Split Rock groundwater development project; prepared for the Wyoming Water Development Commission, variously paged.	Natrona County	Kortes aquifer Moonstone aquifer Split Rock aquifer	Construction of two deep test wells and one test production well to fully evaluate the Split Rock prospect for ground water utilization.	The Splitrock aquifer is a closed aquifer with an average transmissivity of 48,000 gpd/ft, storativity of 0.0001, and specific capacity of 11 gpm/ft respectively.	N/A

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Citation(s)	Location	Aquifer/ Formation	Project Description	Results/Recommendations	Current Status
Weston Engineering, Inc., 2008, Douglas ground water level II study, final report: prepared for the Wyoming Water Development Commission, variously paged.	Converse County	Casper Formation	A Level II Feasibility study for the Water System master Plan to evaluate and provide recommendations concerning the town of Douglas's water supply.	Evaluation of existing facilities results in replacement of certain portions of the current facilities.	N/A
Hinekley Consulting, 2009, in association with Wyoming Groundwater, Lusk area groundwater level I study, final report: prepared for the Wyoming Water Development Commission, variously paged.	Niobrara County	Arikaree Formation	Collect necessary hydrologic data to determine if a Groundwater Control Area should be established.	Groundwater supply within the aquifer is sustainable at the current rate of use. Increased rate of pumping could create drawdown that is unsustainable.	Acquire necessary permits to produce groundwater from the aquifer.
JR Engineering, 2009, Laramie County Aquifer Study, Final Report, 110 p.	Laramie County	High Plains aquifer	Laramie County aquifer Study to determine the hydrologic state of the High Plains aquifer within Laramie County.	There are currently over 12,000 permits issued for wells in the county. All precipitation is a source of recharge for the aquifer. Projected water use ranges from 5,299-10,066 acre feet per year with 25-42 actively pumping wells.	N/A
JR Engineering, 2009, in association with Lidstone and associates, Inc., Master plan level I study for the Town of Pine Bluffs, WY: prepared for the Wyoming Water Development Commission, variously paged.	Laramie County	Brule aquifer Lance aquifer	Level I study to review the existing system and present system upgrades for the town of Pine Bluffs.	Wells into the Lance aquifer were constructed in order to create a consistent supply source in conjunction with inconsistent Brule aquifer after a 20 foot decline and dewatering in some locations.	Proceed with Level II study
Trihydro Corporation, 2009, Belvoir Ranch High Plains aquifer—White River study, project report: prepared for the City of Cheyenne, Board of Public Utilities, and the Wyoming Water Development Commission, variously paged.	Laramie County	White River Formation	Groundwater production potential from the White River Formation in the vicinity of the Belvoir Ranch.	The data collected during the survey suggests that the White River Formation in this vicinity will not yield sufficient water for use as a municipal supply for the city of Cheyenne.	N/A
Wyoming Groundwater, LLC, 2009, in association with WWC Engineering, Glendo water supply level II study: prepared for the Wyoming Water Development Commission and the Town of Glendo, variously paged.	Platte County	Quaternary Alluvium Arikaree Formation White River Formation Permian-Triassic Red Bed Sequence Hartville Formation	Glendo Water Supply Level II Study to define water supply capabilities and demand, identify water supply improvement options, perform well siting studies, construct and evaluate a test well, and provide conceptual designs for proposed system improvements.	The current supply capacity complies with WDEQ regulations; however it does not comply with future demand increases. Pilot Hole # 5 is the most favorable site for a new municipal well with test results of 200 gpm of good quality water. Recommendations include purchasing well at Pilot Hole # 5 from WWDC and installing a pressure transducer to define water level fluctuations.	N/A
DOWL HKM, 2010, in association with Weston Engineering, Inc. and CEPI, Douglas master plan level I study, final report: prepared for the Wyoming Water Development Commission and the City of Douglas, variously paged.	Converse County	Ogallala Formation through Fremont Canyon Sandstone	Douglas Master Plan Level I Study to evaluate the existing water system, and recommend improvements to the system. Some improvements may require studies outside the scope of this Level I study.	City should begin planning for additional supply as it is only slightly greater than current peak day use. Possible developable groundwater supplies were identified that would meet short-term and long-term needs.	It is recommended that a request for Level III funding be made for replacement and rehabilitation of existing facilities.

Appendix B WWDC Groundwater Studies

Citation(s)	Location	Aquifer/ Formation	Project Description	Results/Recommendations	Current Status
Jehn Water Consultants, Inc., 2010, in association with Tetra Tech, Laramie water management study level II phase II, final report, prepared for the Wyoming Water Development Commission, variously paged.	Albany County	Casper aquifer	As part of the previous Level II, Phase II project completed by Tetra Tech in May of 2010, an Aquifer Storage and Recovery (ASR) test was done on the Spur well field. This report examines the possibility of storing water in the Casper aquifer for use during peak demands as part of the ASR test.	Water injected into the aquifer through an injection well during four steps increased the water level in the Spur Well No. 1 approximately 30 m away, 2.3 feet. Eight days after the testing the water level remained 0.79 feet higher than the prior static water level. Water quality was virtually unchanged by the process. It is recommended that production wells be drilled that penetrate all five members of the Casper aquifer.	N/A
Tetra Tech, 2010, Laramie water management phase II level II water system report, final report: prepared for the Wyoming Water Development Commission, variously paged.	Albany County	Casper aquifer	Phase II, Level II Water System Report for the city of Laramie. Scope of study includes: GIS work, hydraulic modeling, aquifer storage and recovery study, and long-term groundwater treatment of the Casper aquifer.	The existing hydraulic water model of the city's distribution system was updated and calibrated, required more work than initially planned, therefore elements of the original scope of work were abandoned. It is recommended that the South Laramie Connection be designed.	N/A
Wester Wetstein & Associates, 2010, in association with James Gores & Associates and Olsson Associates, City of Rawlins water master plan level I, final report: prepared for the Wyoming Water Development Commission and the City of Rawlins, variously paged.	Carbon County	Nugget Formation	Rawlins Water Master Plan Level I provides a working model of the distribution system and examines the adequacy of the existing supplies to meet projected needs.	Overall the water system was found to be in great condition, however many improvements are needed and include the replacement of the pipeline between the Water Treatment Plant Pipeline and Atlantic Rim Reservoir, and establishing a program of usage for the Nugget wells.	WWDC has begun the process of appropriating funds for the new pipeline.
Wester Wetstein & Associates, 2010, in association with James Gores & Associates and Olsson Associates, Town of Wheatland master plan level I study, final report: prepared for the Wyoming Water Development Commission and the Town of Wheatland, variously paged.	Platte County	Arikaree Formation	Wheatland Master Plan Level II Study gives an overview of the town's water system by identifying areas of improvement, and provides a planning horizon for the next 30 years.	The current supply is sufficient for future demand. System is operated very effectively with no need of any major modifications. Some of the pumps in the booster stations appear to have substantial wear. It is recommended that pump inspections be performed to check their condition.	N/A
Lytle Water Solutions, LLC, 2011, Managed aquifer recharge, storage and recovery project, final report, prepared for the Wyoming Water Development Commission and the Cheyenne Board of Public Utilities, variously paged.	Laramie County	Ogallala aquifer White River aquifer Casper Formation	A multi-phase investigation of the feasibility and benefits of aquifer storage and recovery (ASR) technologies on applicable well fields near Cheyenne.	The Ogallala aquifer is experiencing water level declines that may be related to a number of factors. There will most likely be years with excess water, so a full-scale recharge operation is favorable.	N/A

Appendix B WWDC Groundwater Studies

Citation(s)	Location	Aquifer/ Formation	Project Description	Results/Recommendations	Current Status
PMPC, 2011, in association with Hinekley Consulting, Groundwater exploration program Riverside No. 7 Well, Sierra Madre Water and Sewer Joint Powers Board prepared for the Wyoming Water Development Commission, variously paged.	Carbon County	North Park Formation	Groundwater Exploration Program for Town of Riverside No. 7 Well. Goal is to complete and test an additional water-supply well.		N/A
WWC Engineering, 2011, in association with Wyoming Groundwater, Lance Creek water supply study level I: prepared for the Wyoming Water Development Commission, variously paged.	Niobrara County	Inyan Kara Group	Level I water Supply Study for the Town of Lance Creek, Examine the town's public water system and current groundwater wells	Recommend Level II Study (in progress) and installation of test wells to find new source water for town.	Groundwater study in progress.

Appendix C

*GIS Dataset Sources for
Figures and Plates*

James Stafford and Tomas Gracias

Appendix C - GIS Dataset Sources for Plates and Figures.

Dataset	Presented in	Original Source
GEOLOGY		
Platte River Basin faults	Plate I	Stoeser, D.B., et al., 2005
Precambrian basement structure	Plate I	Blackstone, 1993
Precambrian basement faults	Plate I	Blackstone, 1993
Lineaments	Plate I	Cooley, 1986
Bedrock Geology	Plate I, Plate II	USGS, 2005
Hydrogeology	Plate II	Bartos, T.T., 2012
Cross section lines	Plate I	See GEOLOGIC CROSS SECTIONS
WSGS Regions	Figure x-x.	WSGS/USGS, 2012
GEOLOGIC CROSS SECTIONS		
Geologic cross section A-A'	Figure x-x. Geologic cross section A-A'	Love, 1970
Geologic cross section B-B'-B''	Figure x-x. Geologic cross section B-B'-B''	Trihydro, 2008
Geologic cross section C-C'	Figure x-x. Geologic cross section C-C'	Blackstone, Jr., D.L., 1993
Geologic cross section D-D'	Figure x-x. Geologic cross section D-D'	Cserna, E.G.; Kerns, G.J.; Laraway, W.H., 1983
Geologic cross section E-E'	Figure x-x. Geologic cross section E-E'	Harshman E.N., 1968
Geologic cross section F-F'	Figure x-x. Geologic cross section F-F'	Blackstone, Jr., D.L., 1993
Geologic cross section G-G'	Figure x-x. Geologic cross section G-G'	Blackstone, Jr., D.L., 1969
Geologic cross section H-H'	Figure x-x. Geologic cross section H-H'	Blackstone, Jr., D.L., 1969
Geologic cross section I-I'	Figure x-x. Geologic cross section I-I'	Blackstone, Jr., D.L., 1969
Geologic cross section J-J'	Figure x-x. Geologic cross section J-J'	Ver Ploeg, A.J., 2007
Geologic cross section K-K'	Figure x-x. Geologic cross section K-K'	Ver Ploeg, A.J. and McLaughlin, F.J., 2009
Geologic cross section L-L'	Figure x-x. Geologic cross section L-L'	Ver Ploeg, A.J., 2009
Geologic cross section M-M'	Figure x-x. Geologic cross section M-M'	Ver Ploeg, A.J., 2007
Geologic cross section N-N'	Figure x-x. Geologic cross section N-N'	Blackstone, Jr., D.L., 1996
Geologic cross section O-O'	Figure x-x. Geologic cross section O-O'	Blackstone, Jr., D.L., 1996
Geologic cross section P-P'	Figure x-x. Geologic cross section P-P'	McLaughlin, J.F.; Stafford, J.E.; Harris, R.E, 2011
Geologic cross section Q-Q'	Figure x-x. Geologic cross section Q-Q'	Harris, R.E.;McLaughlin,J.F.;Jones,R.W., 2006
Geologic cross section R-R'	Figure x-x. Geologic cross section R-R'	Harris, R.E.;McLaughlin,J.F.;Jones,R.W., 2005
Geologic cross section S-S'	Figure x-x. Geologic cross section S-S'	Blackstone, Jr., D.L., 1996

GROUNDWATER		
Anomalous geothermal gradients	Figure x-x.	Hinckley and Heasler, 1984 Buelow, 1986
Aquifer recharge as a percent of precipitation	Figure x-x.	Hamerlinck and Arneson, 1998
Aquifer sensitivity	Figure x-x.	Hamerlinck and Arneson, 1998
Average annual precipitation, 1961-1990	Figure x-x.	Daly and Taylor, 1998
Colorado groundwater well permit	Ch.8 Figures	Colorado Division of Water Resources
Environmental water sample locations	Figure x-x.	USGS, Environmental water sample locations GIS dataset of 2010
Estimated net annual aquifer recharge	Figure x-x.	Hamerlinck and Arneson, 1998
Green Areas	Figure x-x.	Hinckley, 2006
Groundwater Control Areas	Figure x-x.	Wyoming State Engineer's Office, 2012
Nebraska groundwater well permit	Ch.8 Figures	Nebraska Department of Natural Resources
Produced water sample locations	Figure x-x.	USGS, Wyoming Water Science Center, 2010
Springs	Figure x-x.	Stafford and Gracias, 2009
SWAP locations	Figure x-x.	Trihydro Corporation, 2004
North Platte Groundwater Assessment Targets	Figure x-x.	Trihydro, 2004
Groundwater Development Potential for the Paleozoic Aquifer SE Wyoming	Figure x-x.	Western Water Consultant's Inc, 1982
Platte/Goshen Regional Water Plan Groundwater Prospects	Figure x-x.	Trihydro, 2004
WSEO groundwater permits	Ch.8 Figures	Wyoming State Engineer's Office, e-Permit database of 2011
POTENTIAL GROUNDWATER CONTAMINANTS		
Abandoned mine sites	Figure x-x.	WDEQ Abandoned Mine Land table of 2010
Active coal mine	Figure x-x.	WDEQ, 2011
Active injector and disposal wells associated with oil and gas		WOGCC well header data as of 2011
Active large mine permits	Figure x-x.	WDEQ Land Quality Division (LQD) large and small active mine permit tables of 2010
Active small mine permits	Figure x-x.	WDEQ Land Quality Division (LQD) large and small active mine permit tables of 2010
Active limited mine operations (ETs)	Figure x-x.	WDEQ LQD limited mine operation GIS dataset of 2009

Active storage tanks	Figure x-x.	WDEQ Solid and Hazardous Waste Division (SHWD), 2011
Active Wyoming Pollutant Discharge Elimination System (WYPDES) outfalls	Figure x-x.	WDEQ Water Quality Division (WQD) WYPDES GIS dataset of 2009
Expired Wyoming Pollutant Discharge Elimination System (WYPDES) outfalls	Figure x-x.	WDEQ Water Quality Division (WQD) WYPDES GIS dataset of 2009
Concentrated Animal Feeding Operations (CAFOs)	Figure x-x.	WDEQ/WQD CAFO table of 2009
Known contaminated groundwater areas	Figure x-x.	WDEQ/WQD Groundwater Program known contaminated areas GIS dataset of 2009
Oil and gas fields (polygons)	Figure x-x.	De Bruin, 2007
Oil and gas fields (points)	Figure x-x.	De Bruin, 2007
Orphan sites	Figure x-x.	WDEQ SHWD orphan site GIS dataset of 2009
Permanently abandoned injector and disposal wells associated with oil and gas	Figure x-x.	WOGCC well header data as of 2011
Pipelines (not for distribution)	Figure x-x.	Wyoming Pipeline Authority pipeline GIS dataset of 2007
Refineries	Figure x-x.	WSGS/WOGCC
Solid and hazardous waste facilities	Figure x-x.	WDEQ SHWD solid and hazardous waste facilities table of 2009
Underground Injection Control (UIC) Class I and V wells	Figure x-x.	WDEQ/WQD UIC GIS dataset of 2011
Voluntary Remediation Program (VRP) sites	Figure x-x.	WDEQ SHWD VRP tables and GIS datasets of 2010
WSGS mines, pits, mills, and plants	Figure x-x.	Harris, 2004
BASE DATA		
Basin boundaries	Plate I, Various figures	U.S. Department of Agriculture, 2002
Hillshade	Various figures	U.S. Geological Survey, 1999
Elevation	Various figures	U.S. Geological Survey, 1999
Lakes	Plate I, Various figures	
Rivers	Plate I, Various figures	
Wyoming, Colorado, and Montana towns	Plate I, various figures	National Atlas of the United States, 2004

Appendix D

Criteria for Hydrologic Connection

Bern Hinckley

HINCKLEY

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MEMORANDUM

TO: Matt Hoobler

DATE: February 7, 2011

FROM: Bern Hinckley

PROJECT: North Platte Technical Support

SUBJECT: Hydrological Connection

This memo has been prepared at the request of the Wyoming State Engineer's Office (SEO) to provide background and screening criteria for assessment of "hydrological connection" of groundwater wells in the North Platte River Basin under the provisions of the Modified North Platte Decree and the Platte River Recovery Implementation Program (PRRIP), i.e. the "28:40" connection criteria. Following discussion of the origin and associated principles, a step-by-step approach to application is suggested. The final section provides references and calculation tools.

BACKGROUND / HISTORY

MBSA, 1982. For a series of reports published in 1982, the Missouri Basin States Association developed an analysis of the impact of groundwater development on streamflow, i.e. "stream depletion", for the Platte and Kansas Rivers and their major tributaries, including the North Platte River (MBSA, 1982). This work developed a series of maps which included lines of equal hydrological connection for groundwater wells along the studied rivers, i.e. all wells along a given line would have the same depletive effect on the stream, as a proportion (percentage) of their groundwater pumping.

These maps were based on the concept of a "stream depletion factor" (sdf), as developed by Jenkins (1968). In an ideal aquifer/stream system (Figure 1) the rate of stream depletion can be estimated as a function of:

- a = distance from the well to the stream (ft.);
- S = specific yield of the intervening aquifer (dimensionless); and
- T = the transmissivity of the intervening aquifer (ft²/day).

using mathematical relationships published by Glover and Balmer (1954). Jenkins combined these factors into a single term, "sdf", and provided tables and graphs relating sdf with stream depletion rates and volumes to simplify the calculations and to facilitate calculations for complex pumping patterns (like seasonal irrigation).

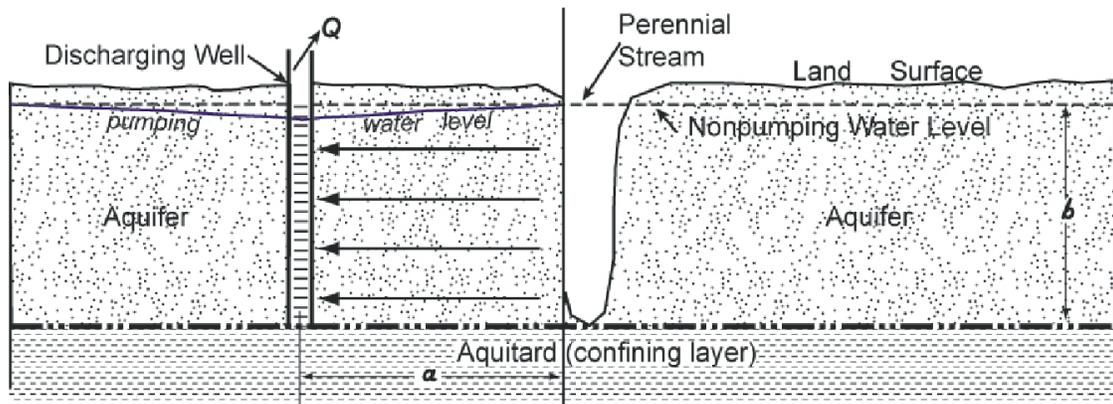


Figure 1 - Idealized "Glover" Model

In the idealized system of Figure 1:

$$sdf = a^2S/T$$

For non-ideal systems, Jenkins proposed an "effective value" of sdf be determined which incorporates, for example, "irregular impermeable boundaries, stream meanders, aquifer properties and their areal variation, distance from the stream, and imperfect hydraulic connection between the stream and aquifer." (Jenkins, 1968; p. 2). For the MBSA (1982) study, which was primarily concerned with stream depletion through groundwater development of the limited-width alluvial aquifers along major streams, sdf values were determined through numerical groundwater modeling of representative stream reaches.

The units of sdf are days. "When the well is pumped continuously and when the volume of depletion reaches 28 percent of the total volume pumped, the pumping time would be approximately equal to one sdf at the well." (MBSA, 1982; p. 9). For example, at a point in the aquifer where the combination of local transmissivity, specific yield, and distance create an sdf value of 500 days, the cumulative stream depletion after 500 days of pumping will be 28%. The cumulative depletion will be less than 28% at 400 days and more than 28% at 600 days. 28% is simply the cumulative depletion at the point in time where the pumping time is numerically equal to the sdf value.

Available data on specific yield and transmissivity were compiled for the aquifers along the streams of interest and the points at which the cumulative stream depletion equaled 28% of the volume pumped at specified times were calculated. These points defined a series of "sdf lines", which were extended loosely parallel to the studied streams -- greater sdf values at greater distance from the stream, smaller sdf values at smaller distances from the stream. Five sdf bands were developed and plotted on these maps, for sdf = 50, 500, 1500, 5,000, and 15,000 days.

15,000 days is approximately 40 years, which was the planning horizon adopted for the overall study program (1944 - 1983). Thus, the cumulative depletion from a point on the outermost mapped line (sdf = 15,000 days), after 40 years of continuous pumping, would be 28%.

The MBSA (1982) study then estimated pumping volumes from irrigations wells within each sdf band (between two sdf lines) and used the sdf bands to calculate the resulting streamflow depletions. Rather than extending explicit calculations to irrigation wells beyond the 15,000-day (40-year) band, all wells outside this line were simply assumed to have an aggregate instantaneous depletive impact of 2% of the amount pumped¹.

Modified North Platte Decree. As streamflow depletion by groundwater irrigation developed as an issue in the 1986 - 2001 Nebraska v. Wyoming lawsuit over the flows of the North Platte River (U.S. Supreme Court No. 108, Orig.), the parties' experts sought to quantify the impact on streamflows of irrigation well development over the period since the original (1945) North Platte Decree. Eventually, the settlement negotiations that resolved the lawsuit, resulting in the 2001 Modified North Platte Decree, boiled the groundwater-irrigation issue down to an assessment of which tracts of groundwater irrigation would be accounted under the agreed-upon limitations on total irrigated acreage and total consumptive use of irrigation water in various sub-basins of the North Platte River in Wyoming. For the North Platte River basin above Guernsey Dam both irrigated acreage and consumptive use limits were established; for the lower Laramie River basin (east of the Laramie Mountains) exclusive of the Wheatland Irrigation District, only an irrigated acreage limitation was established. As a negotiated criteria for identification of which irrigated areas would "count" and which would not, the parties adopted a concept of "hydrological connection" based on the location of the groundwater irrigation supply well:

"A hydrologically connected groundwater well is one that is so located and constructed that if water were intentionally withdrawn by the well continuously for 40 years, the cumulative stream depletion would be greater than or equal to 28% of the total groundwater withdrawn from the well." (North Platte Decree Committee Charter - Exhibit 4, Sec. III, D, 2, b.)

For an initial definition of irrigation wells for which the associated irrigated acreage would be accounted under the Modified Decree, maps were developed by Wyoming and approved by the North Platte Decree Committee (NPDC) based on the best available hydrogeologic information. (No new aquifer data were developed for that analysis.) In some cases, e.g. the lower Laramie River basin, the delineation of "hydrological connection" under the 28:40 criteria was based on existing numerical modeling (i.e. MODFLOW). In most cases, the simpler, stream-depletion

¹No details are provided on the origin of the 2% estimate; the authors "recommend that criteria for areas outside the study limits of the SDF technique be developed and used in the next study."

factor approach (Jenkins, 1968), with $sdf = a^2S/T$, was used². The areas on these maps outside the 28:40 areas, shown in green, i.e. those areas judged not to be “hydrologically connected” under the 28:40 criteria, have come to be known as the “green areas”, in the sense of a “green light” with respect to Decree restrictions on groundwater use.

Because the streamflows of interest were those entering Nebraska from Wyoming’s North Platte River Basin, the stream impacts of concern are those contributing to (or subtracting from) flows at the stateline. Depletions to certain streams, which do not directly contribute to flows at the stateline, do not fall under the Modified Decree “hydrological connection” criteria. As per the procedures adopted by the NPDC, qualifying depletions are those to “perennial streams” which flow through to the mainstem of the North Platte River, as defined by the standard 1:100,000-scale topographic maps produced by the U.S. Geological Survey.

In Wyoming, there are many ephemeral streams which, when they flow at all, are essentially perched above the local groundwater table. These streams lose streamflow to groundwater, but the rate of loss is not affected by the elevation of the underlying groundwater table. A lowering of the groundwater table through pumping does not affect the rate of streamflow loss. No “depletion” occurs as a result of groundwater pumping under these circumstances.

Streams in the mountains of Wyoming are commonly perennial, gain water through groundwater inflow, and can be depleted through groundwater pumping. However, many of these streams become ephemeral once they exit the mountains, losing all perennial flow to the underlying aquifers (e.g. an alluvial fan at the mouth of a stream canyon). Because a depletion to such a stream is not directly translated through to the mainstem of the North Platte River and thus to the stateline, no “depletion” is considered to occur under the Modified Decree. (A more complex analysis is needed in areas where a depleted perennial stream becomes ephemeral close enough to a mainstem tributary that a 28% depletion may occur via the remaining, groundwater connection in less than 40 years.)

Included with adoption of the criteria defined for hydrological connection and the initial hydrological connection maps, was recognition that the maps approved by the NPDC were deliberately conservative, intended to err on the side of smaller rather than larger “green” areas. Because many areas which had not been identified as “green” might still have depletions of less than 28% in 40 years, the NPDC procedures allow case-by-case application of the criteria based on local data and more detailed studies. For example, the hydrological connection between a stream and a nearby well developing groundwater from a deep, confined aquifer might be quite small despite the fact that, in map view, the well is relatively close to the stream.

²In the absence of a more complicated determination of an effective sdf value, Jenkins (1968) is essentially reduced to the configuration of Figure 1 and the equations of Glover and Balmer (1954). Narrow, high-transmissivity alluvial aquifers are largely ignored as being clearly within the bounds of “hydrological connection”. (See individual map descriptions for details.)

As of this writing, Modified Decree compliance with respect to annual irrigated acreage and consumptive use accounting associated with hydrologically-connected groundwater is based on the NPDC “green area” maps and a small number of individual site studies that have applied the 28:40 criteria outside the previously defined areas.

Platte River Recovery Implementation Program (PRRIP). Similar issues regarding the impact of groundwater development on streamflow were subsequently resolved in the development of the Platte River Recovery Implementation Program (PRRIP). Recognizing that beyond a certain degree of hydrological connection, the estimation and accounting of groundwater impacts fell below an appropriate level of concern, the parties to that program negotiated adoption of the 28:40 hydrological connection criteria from the Modified North Platte Decree. With the same provisions for future individual studies, hydrological-connection maps as described above were developed for the remaining portions of the North Platte River basin in Wyoming (North Platte River below Guernsey Dam and upper Laramie River basin) and it was agreed that groundwater development outside the 28:40 bounds would be exempt from the recovery program.

As of this writing, PRRIP compliance with respect to 1997 “baselines” and calculation of “new” depletions are based on the “green area” maps in the Wyoming Depletion Plan and a small number of individual site studies that have applied the 28:40 criteria outside the previously defined areas.

The SEO website (<http://seo.state.wy.us/>) provides electronic versions of the “green area” maps for the various North Platte River sub-basins, and related policy documents.

PRINCIPLES

In principle, nearly all sources of groundwater are connected to surface water resources to some degree. Exceptions include connate water (e.g. sea water remaining since the original deposition of a formation) and, sometimes, water associated with hydrocarbon deposits. For the most part, groundwater of sufficiently high quality to be of value for irrigation, domestic, municipal, and stock use is likely to be part of an active groundwater flow system that, however slowly, begins and ends at the earth’s surface.

The basic, physical constraint of “mass balance” requires that any increase in groundwater consumption at one point must be balanced by an equal decrease in storage or consumption somewhere else. For groundwater systems in which the hydrological connection with surface water is small, most of the extracted groundwater comes from storage within the aquifer. This is reflected in a decrease in aquifer water level or pressure (head). For groundwater systems in which the hydrological connection with surface water is large, most of the groundwater comes from surface depletions, and there may be little change in aquifer water levels. A third possible “source” of groundwater is a decrease in withdrawals elsewhere. For example, the term “ET salvage” is applied where the consumption of water by non-beneficial vegetation or natural evaporation is reduced as groundwater is withdrawn for crop consumption, with no decrease in

streamflow or in aquifer storage (beyond the initial water-level drop that dries up the impacted evapotranspiration).

Thus, “hydrological connection” is rarely a binary, “connected” vs. “not connected” assessment. Instead, the reasonable working hypothesis is that aquifer and stream are connected, and one seeks to estimate or measure the degree of connection, commonly with reference to some regulatory, negotiated, or policy standard criteria. The 28:40 criteria presented in the Modified North Platte Decree for accounting and compliance with limitations on irrigated acreage and the consumptive use of irrigation water is an example of such a standard. That same standard was adopted by the parties to the PRRIP for their accounting and replacement water calculation procedures.

Other programs and jurisdictions have adopted different standards, for different purposes. In Colorado, for example, groundwater development that is calculated to have a 0.1% depletive effect in 100 years is considered “tributary” to surface water. The 2004 Platte River Conjunctive Management Study in Nebraska stated, “Hydrologic connection exists where pumping will cause a streamflow depletion within 50 years greater than 10% of the pumping rate.” The latter example also differs from the 28:40 criteria in that it specifies a rate of depletion, rather than being based on the cumulative volume of depletion. (Under steady pumping, the rate of depletion, e.g. in gpm, will always be higher as a percentage of the pumping than the cumulative volume of depletion will be, because small depletion rates early in the pumping period will average out the higher depletion rates of later in the pumping period.)

The hydrological connection criteria cited above, including the 28:40, are all based on proportions rather than absolute volumes. For example, a stream depletion of 50 ac-ft would not be considered “connected” under the 28:40 criteria if the cumulative volume pumped over 40 years were more than 200 ac-ft (i.e. a 25% depletion), whereas a stream depletion of 5 ac-ft would be considered “connected” if the cumulative volume pumped were less than 17 ac-ft (i.e. a 29% depletion). High-yield wells are neither more nor less likely to be meet the criteria for hydrological connection than low-yield wells; nor is there any production threshold below which depletion is automatically considered inconsequential.

Beyond the consideration of groundwater impact with respect to whether a stream is perennial or not (discussed above), a proportion-based criteria for hydrological connection like the 28:40 is inherently insensitive to the flow rate of the stream. This creates an algebraic breakdown for particularly small streams, in that a 1000 gpm well cannot possibly exceed a depletion rate of 10% if the impacted stream only flows 100 gpm in the first place, regardless of distance, transmissivity, time, etc. To date, this issue has not been addressed with respect to application of the Modified Decree and PRRIP “hydrological connection” criteria.

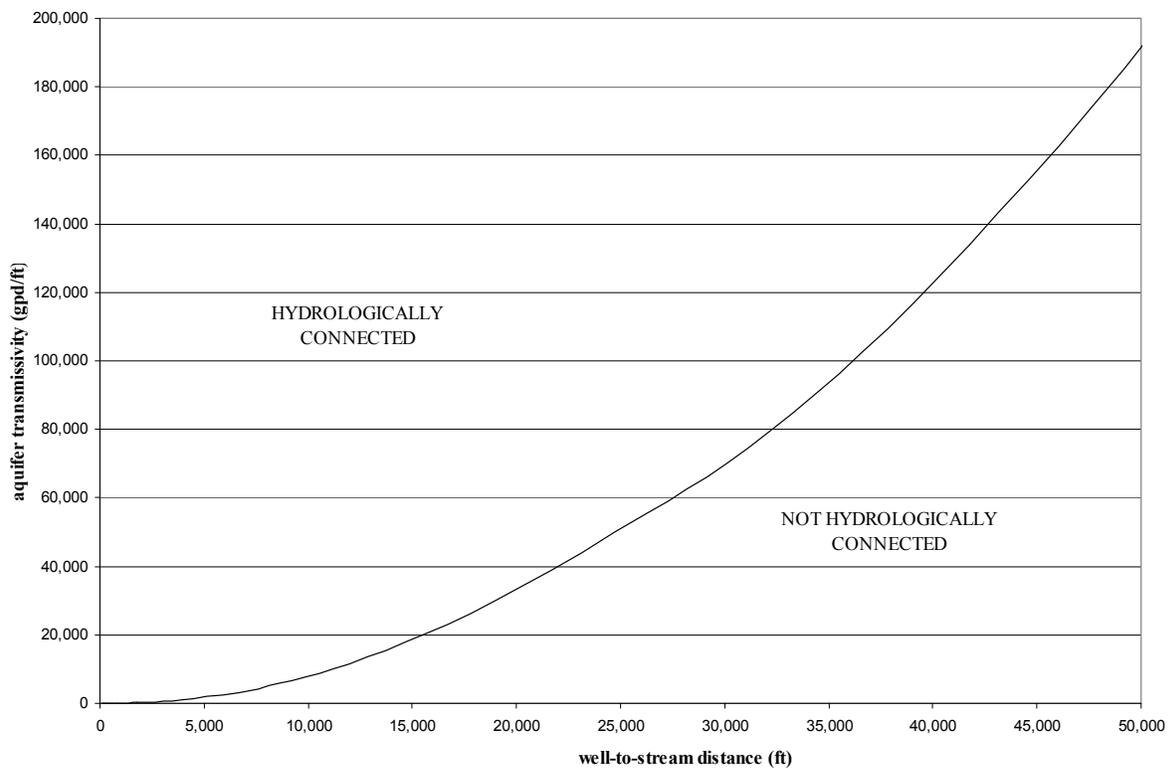
Hydrological connection is calculated under the 28:40 criteria without regard to the flow direction of groundwater. Stream depletion resulting from water physically leaving the stream to enter the aquifer being pumped is treated the same as stream depletion resulting from pumping

groundwater that would otherwise flow on into the stream. This reflects the hydrologic principle of “superposition” which recognizes that the impact of a pumping well is simply added to whatever other stresses, gradients, impacts, etc. are otherwise present.

APPLICATION

Figure 2 presents the 28:40 criteria for hydrological connection as calculated for an ideal (i.e. thick, homogeneous, isotropic, “sandbox”) aquifer. The figure assumes a generic, unconfined-aquifer specific yield of 0.15, then plots the line along which the transmissivity and distance parameters produce a 28% cumulative depletion in 40 years. The area above and to the left of the line represents wells for which either the distance to the stream is small enough and/or the transmissivity is high enough that the depletion is greater than 28%. Only where the distance is large enough or the transmissivity is small enough (the right-hand side of the graph), will wells in this idealized scenario be classified as “not hydrologically connected”.

**Figure 2 -- 28% Depletion in 40 Years (S = .15)
idealized aquifer**



Consider an 8-inch diameter municipal-supply well for which the desired yield is 300 gpm. Under the idealized conditions of Figure 2, for drawdown to remain within reasonable magnitude, say 300 ft., a transmissivity in excess of 1,500 gpd/ft is required³. Such a well would have to be at least 4,400 ft from the stream to be considered not hydrologically connected under the 28:40 criteria. Absent contrary indications (discussed below), productive wells closer to the stream are likely be classified as “hydrologically connected” under the 28:40 criteria.

Given enough time, one might address the question of hydrological connection through direct observation, i.e. pump a well, measure flow in the potentially impacted stream, and see what happens. In practice, the 28:40 threshold for “connection” is likely too low to be directly assessed. Typical pump tests are run from a few hours to a few days. Where a critical factor in an important project cannot be adequately investigated without a longer test (e.g. delayed yield or where aquifer boundaries are expected), multi-week pump tests are occasionally justified. However, for a well in an ideal aquifer to fall outside the 28:40 criteria, the depletion rate over even a 60-day test would be less than 0.01% - almost certainly too small to be detected by direct streamflow measurements. If any discernable depletion were measured in a direct test, it would be clear that the well would be classified as “connected” under the 28:40 criteria, but the absence of discernable depletion could not be interpreted to mean the well would be classified as “not connected”.

Thus, assessment of hydrological connection under a 28:40 criteria is almost inevitably based on groundwater theory (modeling), where aquifer hydrogeologic parameters are quantified and used to mathematically predict impacts over extended time periods, rather than relying on direct observation. Suitable models of aquifer behavior for predicting stream depletion impacts vary from such simple, 3-parameter equations as the “sdf” method described above (and used to develop Figure 1), to complex, multi-layer numerical models such as those built within the MODFLOW⁴ structure.

Hydrogeologic Parameters

Specific yield (storage coefficient; storativity). This parameter is necessary for even the simplest models, as it reflects the volume of water available for each increment of drawdown. The higher the specific yield, the more of the pumping demand that is met by release of aquifer storage and the less that is met by stream depletion. Specific yield values for the unconfined aquifers associated with surface interaction commonly fall in the range of 0.10 - 0.20. Storage coefficients derived from short-term pump tests should be evaluated with care, in that initially low, confined-aquifer values may approach unconfined-aquifer values over the extended time

³The conversion between transmissivity units is: $1 \text{ ft}^2/\text{day} = 7.48 \text{ gpd/ft}$

⁴MODFLOW is a standard, finite-difference groundwater flow model developed by the U.S. Geological Survey. There are many commercial versions of this model, for which graphical pre- and post-processors have been added to facilitate use.

periods of interest here, i.e. a 40-year view that includes “delayed yield” reactions, the spread of drawdown into unconfined portions of a locally confined aquifer, etc.

Transmissivity. This parameter is also necessary for even the simplest models, as it reflects the ease with which water moves through the aquifer, between stream and well. Higher transmissivities produce higher stream depletion, all else being equal. Typically, wells are sited to maximize transmissivity, e.g. targeting coarse-textured zones or fracture zones, whereas the wider-area of the aquifer between well and stream may have a lower effective transmissivity. Use of a transmissivity value from a singularly productive well may thus be conservative in the sense of tending to overestimate stream depletion. Similarly, because transmissivity is the product of permeability and aquifer saturated thickness, transmissivity will decrease as drawdown develops in an unconfined aquifer. Simple models of stream depletion assume an effectively constant transmissivity (i.e. that the saturated thickness does not significantly decrease with pumping), which may not be the case in relatively thin aquifers.

Hydraulic parameters for “confining” units. Based on lithologic considerations or pump-test drawdown measurements in various geologic layers, it may be possible to develop quantitative estimates of the permeability of significant low-permeability zones between the well and stream. The common mistake of a “not hydrologically connected” conclusion based simply on measurement of a head difference between two hydrogeologic units should be avoided. Head differences, whether vertical or horizontal, identify groundwater gradients and the resulting groundwater flow directions. Only combined with credible permeability information can hydrological connection interpretations be supported.

Boundaries. Pump tests of sufficient duration and/or geologic interpretation may provide aquifer boundary information. “Negative” boundaries in a pump test, e.g. when the cone of depression generated by well pumping encounters the termination of a water-bearing unit, suggest greater isolation of the aquifer from its surroundings, decreasing the opportunity for hydrological connection with the surface. “Positive” boundaries, particularly the occurrence of a point in time in a pump test beyond which no additional drawdown takes place, suggest a “recharge” source, the most likely candidate for which is commonly a surface-water feature.

In the development of parameters with which to project hydrological connection, pump-test drawdown data from observation wells can be particularly important in assessment of hydrogeologic conditions through the wider aquifer (away from the pumped wellbore) However, variation in groundwater levels near an impacted stream are strongly limited by the presence of the stream. The stream is depleted as it “works” to maintain adjacent groundwater levels. The perhaps subtle change in groundwater gradients accompanying stream depletion are necessarily less apparent close to the stream. The absence of readily discernable near-stream drawdown in the aquifer cannot be taken as demonstration that a pumped well is having little impact on streamflow.

Hydrogeologic Setting

Most of the initial “green area” maps developed for compliance and application of the Modified Decree and the PRRIP were produced by applying conservative parameters (e.g. using the highest of reasonable transmissivity values) and conservative assumptions (e.g. a continuous, homogeneous aquifer; a fully-penetrating stream) to a simple, idealized model of aquifer behavior, across large areas of the North Platte River basin. This broad approach was deemed inappropriate for geologically complex areas, e.g. much of the area south of the North Platte River between Casper and Douglas, and was recognized as ignoring many factors that, at a local scale, may serve to reduce or enhance hydrological connection. These are factors best addressed on a case-by-case basis, where detailed data collection and interpretation are available, and where site-specific groundwater modeling that takes more information into account can be developed.

In all cases, the general hydrogeologic setting of a well should be considered as part of the assessment of hydrological connection. Where the simple geometry of an aquifer makes the low magnitude of potential connection obvious, e.g. an aquifer with no outcrop within tens of miles, confined beneath several thousand feet of low-permeability shale, limited or no quantitative modeling may be necessary. In any case, the following hydrogeologic factors should be considered in assessment of the appropriate level of analysis:

Stratigraphy. Streams rarely fully penetrate the aquifer, as assumed by the simple, Glover-type models (Fig. 1) Where a well is completed in the deep zones of an aquifer while the stream penetrates only the uppermost zones, the thickness of the aquifer itself may become a significant factor in stream depletion. For this reason, even in a homogeneous aquifer, a shallow well is somewhat more likely to qualify as “connected” than a deep well.

Low-permeability formations/layers between the aquifer and the stream serve to reduce the degree of hydrological connection. Thickness is a key component, of course, in that the thicker the low-permeability layers are, the less the hydrological connection. The lateral continuity of a restricting or confining layer is also important, in that groundwater flow may “short-circuit” a low-permeability unit where the unit is thin or absent.

Geologic Structure. Most of the above discussion assumes horizontal orientations, e.g. an aquifer beneath a low-permeability layer remains separated from the surface at all locations. This conceptualization is incorrect where strata are dipping or are broken by faults or fractures.

Although the aquifer may be separated from the stream by low-permeability intervening strata at the closest point, the aquifer may be exposed to the surface and stream at an up-dip location close enough to meet hydrological connection criteria.

If an inter-formation fault juxtaposes the aquifer against a low-permeability unit between the well of interest and the potentially impacted stream, hydrological connection may be severed or

greatly inhibited. On the other hand, intra-formational faults are generally considered to greatly enhance permeability. If such faulting/fracturing provides a groundwater pathway between aquifer and stream, hydrological connection will be greatly enhanced.

In many bedrock aquifers, fracturing (e.g. associated with faulting) is the predominant source of permeability. As with the faults themselves, fracture zones may provide a high-permeability pathways between well and stream, along which hydrological connection is enhanced.

Stream/Aquifer Continuity. The setting of a “perched” stream, where a stream is hydraulically decoupled from the underlying aquifer by an intervening unsaturated zone, was discussed above. Examination of the distribution of groundwater elevations (heads), e.g. potentiometric surface mapping, particularly with respect to the stream location and water-surface elevation, may assist in the interpretation of hydrological disconnection. A related issue is the hydraulic conductance of the streambed. Due to an accumulation of fine-grained material and organic debris at the streambed, a zone of permeability lower than that of the underlying aquifer may develop, which reduces hydrological connection.

Stream and Aquifer Geometry. The simplified stream depletion calculations assumes a linear stream, extending to infinity in both directions past the well. If much of the stream is further from (or closer to) the well than this assumption, e.g. a regional stream curve, depletion will be less (or more). If a well is located so as to impact more than one stream, the total depletion will be more than is calculated for a single stream. If the aquifer comes to an end within a distance influenced by the well, e.g. an alluvial aquifer pinching out at the valley side, there will be less aquifer storage available to the well than is represented by Figure 1 and stream depletion will be enhanced accordingly.

Recommended Approach

The recommended process for evaluation of hydrological connection under the 28:40 criteria follows:

1. Screen for previous determinations of hydrological connection, e.g. the North Platte Decree and PRRIP “green area” maps. These have been endorsed by the relevant parties for specific application under those compliance programs. Similarly, there is a small number of individual well studies of hydrological connection conducted for various development and permitting purposes which may be relevant to a new investigation. If an area/aquifer has been previously determined to qualify as “not hydrologically connected”, there may be no need for further evaluation. Contact the WSEO North Platte River Coordinator for details.
2. Assess the hydrogeologic setting as discussed above to determine if “hydrological connection” status is obvious. For example, a near-stream well drawing from a shallow aquifer is almost certainly “connected” under the 28:40 criteria. A far-from-stream well drawing from a deep, confined aquifer is likely to be “not connected”.

3. If additional analysis is indicated, compile available aquifer parameter data and apply a simple stream depletion model for general direction and screening-level analysis. The Jenkins (1968) implementation, with an “sdf” calculated directly as $sdf = a^2S/T$, is appropriate for this step. (The Jenkins reference provides a hand-calculator suitable implementation; an electronic spreadsheet formula is provided in the “Tools” section of this memo; AWAS (2011) provides a computerized implementation with input screens and graphical output.)

4. Consider the potential impact of additional hydrogeologic detail on the screening-level analysis. For example, if the “sdf” parameter is simply being calculated from single values of aquifer transmissivity and storativity, it assumes an extensive, homogeneous aquifer. If the well is in an alluvial aquifer that terminates at the valley wall, stream depletion will be greater than calculated by the screening method. If the simplified method suggests “connected”, it is unlikely that more detailed analysis will change that. If the simplified analysis suggests “connected” and there are fracture systems present that would serve to enhance rather than inhibit connection, there may be little point in proceeding (if the hydrological connection issue is just “yes” or “no”, rather than the degree of connection). Similarly, if the simplified analysis suggests “not connected” and qualitative consideration of the hydrogeologic setting demonstrates that conclusion would only be bolstered by more detailed analysis, the “yes/no” question may be considered resolved.

5. If ambiguity remains in the “hydrological connected” evaluation (e.g. the simplified calculation indicates a 35% depletion in 40 years, but there is a low-permeability layer between the well’s completion interval and the stream), identify the critical hydrogeologic parameters necessary for development of a more accurate conceptual model of the stream / aquifer system and design an investigation program focused on elucidating the key components or parameters affecting the conclusion (e.g. the nature of faulting, groundwater vs. surface water elevations beneath a stream, the permeability of overlying strata, etc.)

6. Develop additional aquifer/stream data, e.g. through research, field mapping, water-level measurement, pump testing, etc. as per the previous step.

7. Apply/construct an appropriate groundwater model to quantitatively assess depletion relationships.

Successive steps in the above outline represent greater commitment of resources. If the desired answer is just a “yes” vs. “no” on “connected?” under the 28:40 criteria, the initial screening steps may be sufficient, depending on how close to the 28% value one falls. If the degree of hydrological connection is required, the analysis required will be proportional to the desired level of accuracy. It is more difficult to predict the difference between 22% and 18% depletion with confidence than the difference between 30% and 10%. However, even with the most complete and expensive analysis possible, the results will be based on projection of impacts in an idealized aquifer system and will include some level of error. Ultimately, the decision to proceed with more elaborate analysis should be based on a realistic assessment of the chances of

usefully refining the conclusions, the resources necessary to conduct a credible investigation, and the potential value of the improved understanding potentially available.

TOOLS

This section provides the references cited above, with annotations, a sampling of the scientific literature related to stream depletion, and spreadsheet equations for calculating stream depletion for the idealized aquifer/stream system of Figure 1.

1. The most common, simplified modeling approach to stream depletion is that based on the work of Glover and Balmer (1954). Jenkins (1968) consolidated basic aquifer parameters into a “stream depletion factor” (sdf) to allow application of Glover’s equations to more complex aquifer/stream configurations and to provide simple tables and graphs in lieu of complex mathematical calculations. This same basic formulation is known as “Glover” or “Jenkins” or “sdf” or, in Colorado, the “Schroeder” (Schroeder, 1987) program and its later, modern computer implementation, “AWAS” (2011).

Glover, Robert J. And Glenn G. Balmer; 1954; River Depletion Resulting From Pumping a Well Near a River; American Geophysical Union, Transactions, Vol. 35, No. 3. This is the seminal paper, of interest as an historical foundation, but long-since supplanted by more tractable publications.

Jenkins, C.T.; 1968; Computation of Rate and Volume of Stream Depletion by Wells; U.S. Geological Survey Techniques of Water-Resources Investigations, Chapter D1, Book 4 - Hydrologic Analysis and Interpretation; basically the same paper as:

Jenkins, C.T.; 1968; Techniques for Computing Rate and Volume of Stream Depletion Near Wells; Groundwater, 6, no. 2, pp. 37-46. Jenkins provides a readily usable explanation and non-computer implementation of basic stream depletion, including accommodation of multiple pumping and recovery periods, and including useful examples.

Missouri Basin States Association; 1982; Technical Paper - Ground Water Depletion (and accompanying maps). This work applied the “sdf” method to the major tributaries of the Missouri River, including the North Platte River below Guernsey Dam.

Schroeder, Dewayne R.; 1987; Analytical Stream Depletion Model; Colorado Division of Water Resources, Office of the State Engineer, Ground Water Software Publication No. 1. This user-interactive BASIC program applied the “Glover” equations (or the “Jenkins” approach if an sdf is independently available) to aquifers with boundaries parallel or perpendicular to the stream. Its DOS shell and primitive graphics have been replaced in the AWAS implementation described below.

AWAS - Alluvial Water Accounting System Ver.1.5.75; 2011. This program was developed by the Integrated Decision Support Group at Colorado State University. The AWAS “Original” mode duplicates Schroeder (1987). The latest version of the program, users manual, a quick tutorial, and the above-referenced Jenkins and Schroeder papers can be downloaded from website: <http://www.ids.colostate.edu/projects/idsawas/>

With the advent of electronic spreadsheets implementing advanced mathematical functions, the tabled, graphed, or programmed values in these references that relate depletion to sdf can be readily duplicated as single-cell spreadsheet formulas. In an EXCEL™ spreadsheet, for example:

$$v/Qt = ((sdf/(2*t))+1)*ERFC((sdf/(4*t))^0.5) - ((sdf/(4*t))^0.5)*(2/(PI)^0.5)*EXP((sdf)/(4*t))$$

= the cumulative volume of stream depletion over time t

and,

$$q/Q = 1 - \text{ERF}(0, (sdf/(4*t))^0.5) = \text{the instantaneous rate of stream depletion at time t}$$

where,

$$sdf = a^2S/T = \text{stream depletion factor (days)}$$

and,

a = distance from the well to the stream (ft);

S = specific yield of the intervening aquifer (dimensionless);

T = the transmissivity of the intervening aquifer (ft²/day);

t = pumping time (days);

q = the rate of stream depletion (ft³/day);

Q = the rate of well pumping (ft³/day);

v = cumulative volume of stream depletion (ft³).

2. Analysis, critique, and refinement of this basic approach is provided in the following journal articles (among many others):

Sophocleous, M., A. Kousis, J.L. Martin, and S.P. Perkins; 1995; Evaluation of Simplified Stream Aquifer Depletion Models for Water Rights Administration; Groundwater, Vol. 33, No. 4 uses a numerical model to evaluate some of the simplifying assumptions of the “sdf” approach. The general conclusion is that the “sdf” methods tend to somewhat overstate stream depletion by near-stream wells.

Hunt, Bruce; 1999; Unsteady Stream Depletion from Ground Water Pumping; Groundwater, Vol. 37, No. 1 addresses depletion of a stream that does not fully penetrate the aquifer and which has an inhibiting streambed layer.

Pattle Delamore Partners Ltd & Environment Canterbury; June, 2000; Guidelines for the Assessment of Groundwater Abstraction Effects on Stream Flow; Environment Canterbury (ROO/11)(ISBN 1-86937-387-1) presents extensions of the “sdf” equations to accommodate additional factors like streambed conductance, more than one stream, and springs.

Miller, Calvin D., Deanna Durnford, Mary R. Halstead, Jon Altenhofen, and Val Flory; 2007; Stream Depletion in Alluvial Valleys Using the SDF Semi-analytical Model; Groundwater, Vol. 45, No. 4, pp: 506-514 provides a lucid discussion of the use of the “sdf” parameter to incorporate limited aquifer deviations from ideal conditions, and offers a refinement to better reflect aquifer boundaries.

Reeves, Howard W.; 2008; STRMDEPL08 - An Extended Version of STRMDEPL with Additional Analytical Solutions to Calculate Streamflow Depletion by Nearby Pumping Wells; U.S. Geological Survey Open-File Report 2008-1166 incorporates analytical equations to accommodate partial penetration, streambed conductance, and leaky aquifer parameters.

3. The references cited above provide approaches that are idealized with respect to the nature of the aquifer – typically homogeneous, isotropic, and unconfined – and the overall aquifer/stream system geometry - e.g. fully-penetrating wells and streams, linear streams and aquifer boundaries, single-layer aquifers. Accommodation of more complex conceptualizations of the stream:aquifer system is generally provided through site-specific numerical modeling. Review of the professional literature will find many site-specific examples.

Appendix E

*Summary Statistics for
Environmental Water Samples*

Laura L. Hallberg, and Melanie L. Clark

Appendix E1. Summary statistics for environmental water samples, Sweetwater Arch, Wyoming.

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Quaternary alluvial aquifers	pH (standard units)	6.7	6.9	7.5	8.1	8.3	7
	Specific conductance ($\mu\text{S}/\text{cm}$)	390	400	402	488	576	7
	Hardness (as CaCO_3)	3.9	71.4	131	162	221	7
	Calcium	0.90	20.0	41.0	51.0	72.0	7
	Magnesium	0.40	5.2	8.3	9.0	10.0	7
	Sodium	14.0	21.0	29.0	66.0	140	7
	Potassium	1.5	4.4	4.5	4.7	5.1	7
	Sodium-adsorption ratio (unitless)	0.41	0.72	1.1	3.4	30.9	7
	Alkalinity (as CaCO_3)	134	134	156	190	219	7
	Chloride	7.0	7.1	8.1	16.0	20.0	7
	Fluoride	0.20	0.30	0.40	0.40	1.0	7
	Silica	25.0	28.0	28.0	39.0	43.0	7
	Sulfate	23.0	36.0	45.0	61.0	74.0	7
	Total dissolved solids	252	253	269	304	391	7
	Nitrate+nitrite (as N)	--	0.41	0.43	1.3	1.9	5
	Orthophosphate (as P)	--	0.010	0.020	0.030	0.030	3
	Phosphorus, unfiltered (as P)	--	0.030	0.030	0.070	0.070	3
Boron	--	30.0	40.0	140	140	3	
Selenium	<1.0	--	--	--	--	1	
Aquifers in undifferentiated Miocene rocks	Dissolved oxygen	0.70	--	3.4	--	5.0	3
	pH (standard units)	7.1	7.4	7.8	8.1	8.4	31
	Specific conductance ($\mu\text{S}/\text{cm}$)	132	311	352	796	11,500	30
	Hardness (as CaCO_3)	54.0	100	130	180	3,700	26
	Calcium	18.0	29.0	39.0	51.0	900	27
	Magnesium	2.3	4.8	6.7	16.0	350	26
	Sodium	6.0	15.0	25.5	38.0	1,100	28
	Potassium	0.20	2.4	4.7	6.2	48.0	27
	Sodium-adsorption ratio (unitless)	0.40	0.59	0.95	1.5	7.9	24
	Alkalinity (as CaCO_3)	64.0	108	142	184	460	28
	Bromide	0.13	--	--	--	--	1
	Chloride	1.0	3.3	6.4	11.0	3,900	28
	Fluoride	0.10	0.30	0.40	0.50	1.1	27
	Silica	1.9	24.0	45.0	53.0	67.0	26
	Sulfate	0.60	14.0	27.5	57.5	440	28
	Total dissolved solids	90.0	198	249	320	6,660	28
	Ammonia (as N)	--	0.011	0.032	0.065	2.6	8
	Ammonia+organic nitrogen, unfiltered (as N)	0.16	--	--	--	--	1
	Ammonia, unfiltered (as N)	<0.010	--	--	--	--	1
	Nitrate+nitrite (as N)	--	0.40	0.53	1.5	13.7	18
Nitrate+nitrite, unfiltered (as N)	0.90	--	--	--	--	1	
Nitrate (as N)	--	0.065	0.15	0.37	3.6	16	

2 Appendix E1

Appendix E1. Summary statistics for environmental water samples, Sweetwater Arch, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Aquifers in undifferentiated Miocene rocks—Continued	Organic nitrogen, unfiltered (as N)	0.16	--	--	--	--	1
	Total nitrogen, unfiltered (as N)	1.1	--	--	--	--	1
	Orthophosphate (as P)	--	0.011	0.018	0.025	0.12	8
	Phosphorus, unfiltered (as P)	--	0.030	0.070	0.25	0.65	11
	Arsenic	--	1.0	1.0	5.0	7.0	5
	Boron	--	37.9	76.3	170	460	7
	Cobalt	0.25	--	--	--	--	1
	Iron, unfiltered	--	30.0	50.0	3,000	4,200	7
	Lithium	28.6	--	--	--	30.0	2
	Manganese, unfiltered	30.0	--	--	--	--	1
	Molybdenum	2.0	--	--	--	6.6	2
	Selenium	--	1.3	1.6	1.9	2.0	5
	Strontium	443	--	--	--	--	1
	Vanadium	1.2	--	--	--	3.3	2
	Gross alpha radioactivity (picocuries per liter)	17.0	--	--	--	--	1
	Gross beta radioactivity (picocuries per liter)	--	4.7	7.4	8.5	9.0	4
	Radium-228 (picocuries per liter)	<1.0	--	--	--	--	1
	Radon-222, unfiltered (picocuries per liter)	--	373	401	526	642	4
	Uranium	--	5.2	5.2	10.0	51.0	5
	White River aquifer and confining unit	pH (standard units)	7.3	7.5	7.5	7.6	7.6
Specific conductance ($\mu\text{S}/\text{cm}$)		300	346	382	530	690	5
Hardness (as CaCO_3)		81.4	120	179	225	275	5
Calcium		27.0	35.0	57.0	77.0	87.0	5
Magnesium		3.4	7.3	7.9	8.9	14.0	5
Sodium		9.8	12.0	17.0	23.0	49.0	5
Potassium		2.9	3.4	4.1	6.2	8.5	5
Sodium-adsorption ratio (unitless)		0.32	0.35	0.60	0.70	2.4	5
Alkalinity (as CaCO_3)		148	149	151	164	201	5
Chloride		3.9	5.3	6.2	6.3	8.1	5
Fluoride		0.30	0.30	0.30	0.30	0.70	5
Silica		24.0	42.0	44.0	45.0	67.0	5
Sulfate		5.8	26.0	47.0	86.0	110	5
Total dissolved solids		216	271	282	329	397	5
Nitrate+nitrite (as N)		--	0.25	0.42	0.80	1.0	4
Phosphorus, unfiltered (as P)	--	0.015	0.030	0.045	0.050	4	
Selenium	5.0	--	--	--	--	1	
Wagon Bed aquifer and confining unit	pH (standard units)	7.8	--	--	--	8.3	2
	Specific conductance ($\mu\text{S}/\text{cm}$)	362	--	--	--	510	2
	Hardness (as CaCO_3)	159	--	--	--	160	2

Appendix E1. Summary statistics for environmental water samples, Sweetwater Arch, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Wagon Bed aquifer and confining unit—Continued	Calcium	53.0	--	--	--	55.0	2
	Magnesium	5.6	--	--	--	6.5	2
	Sodium	7.0	--	--	--	46.0	2
	Potassium	3.6	--	--	--	3.6	2
	Sodium-adsorption ratio (unitless)	0.24	--	--	--	1.6	2
	Alkalinity (as CaCO_3)	159	--	--	--	181	2
	Chloride	3.6	--	--	--	7.6	2
	Fluoride	0.20	--	--	--	0.40	2
	Silica	32.0	--	--	--	46.0	2
	Sulfate	9.1	--	--	--	77.0	2
	Total dissolved solids	233	--	--	--	331	2
	Ammonia (as N)	0.020	--	--	--	0.040	2
	Nitrate+nitrite (as N)	0.066	--	--	--	0.75	2
	Nitrate (as N)	<0.066	--	--	--	0.74	2
	Nitrite (as N)	<0.010	--	--	--	0.010	2
	Orthophosphate (as P)	0.020	--	--	--	0.050	2
	Phosphorus, unfiltered (as P)	0.040	--	--	--	0.060	2
Selenium	<1.0	--	--	--	<4.0	2	
Wind River aquifer	Specific conductance ($\mu\text{S}/\text{cm}$)	320	--	--	--	--	1
Frontier aquifer	pH (standard units)	7.9	--	--	--	8.6	2
	Specific conductance ($\mu\text{S}/\text{cm}$)	2,000	--	2,330	--	3,740	3
	Hardness (as CaCO_3)	10.0	--	1,000	--	1,600	3
	Calcium	2.9	--	278	--	442	3
	Magnesium	0.70	--	77.0	--	116	3
	Sodium	166	--	351	--	461	3
	Potassium	1.2	--	5.7	--	6.1	3
	Sodium-adsorption ratio (unitless)	2.3	--	3.8	--	63.0	3
	Alkalinity (as CaCO_3)	234	--	383	--	484	3
	Chloride	9.2	--	35.0	--	73.0	3
	Fluoride	1.2	--	2.0	--	2.1	3
	Silica	3.2	--	11.0	--	19.0	3
	Sulfate	487	--	900	--	2,000	3
	Total dissolved solids	1,280	--	1,740	--	3,330	3
	Nitrate+nitrite (as N)	1.2	--	--	--	--	1
	Nitrate (as N)	0.090	--	--	--	0.70	2
	Boron	--	380	470	1,100	1,100	3
Iron, unfiltered	480	--	--	--	590	2	
Cloverly aquifer	Dissolved oxygen	7.0	--	--	--	--	1
	pH (standard units)	7.3	--	7.4	--	8.3	3
	Specific conductance ($\mu\text{S}/\text{cm}$)	378	--	779	--	2,670	3
	Hardness (as CaCO_3)	4.0	--	168	--	1,800	3
	Calcium	1.4	--	47.6	--	471	3

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Appendix E1. Summary statistics for environmental water samples, Sweetwater Arch, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Cloverly aquifer— Continued	Magnesium	0.10	--	11.8	--	159	3
	Sodium	9.7	--	40.0	--	184	3
	Potassium	0.20	--	2.0	--	2.8	3
	Sodium-adsorption ratio (unitless)	0.33	--	0.41	--	40.5	3
	Alkalinity (as CaCO_3)	101	--	125	--	287	3
	Bromide	0.030	--	--	--	--	1
	Chloride	3.7	--	8.2	--	11.0	3
	Fluoride	0.19	--	0.90	--	1.6	3
	Silica	12.0	--	12.3	--	14.0	3
	Sulfate	82.8	--	98.0	--	1,680	3
	Total dissolved solids	241	--	484	--	2,680	3
	Ammonia (as N)	<0.040	--	--	--	--	1
	Nitrate+nitrite (as N)	0.26	--	--	--	--	1
	Nitrate (as N)	<0.26	--	--	--	1.1	2
	Nitrite (as N)	<0.008	--	--	--	--	1
	Orthophosphate (as P)	<0.020	--	--	--	--	1
	Aluminum	<1.6	--	--	--	--	1
	Antimony	<0.30	--	--	--	--	1
	Arsenic	0.30	--	--	--	--	1
	Barium	57.0	--	--	--	--	1
	Beryllium	<0.06	--	--	--	--	1
	Boron	--	56.0	100	340	340	3
	Cadmium	0.02	--	--	--	--	1
	Chromium	<0.80	--	--	--	--	1
	Cobalt	0.14	--	--	--	--	1
	Copper	0.80	--	--	--	--	1
	Iron	<8.0	--	--	--	--	1
	Iron, unfiltered	130	--	--	--	--	1
	Lead	<0.08	--	--	--	--	1
	Lithium	18.7	--	--	--	--	1
	Manganese	<0.20	--	--	--	--	1
	Molybdenum	2.4	--	--	--	--	1
	Nickel	2.0	--	--	--	--	1
Selenium	2.6	--	--	--	--	1	
Strontium	719	--	--	--	--	1	
Vanadium	0.30	--	--	--	--	1	
Zinc	0.50	--	--	--	--	1	
Radon-222, unfiltered (picocuries per liter)	6,940	--	--	--	--	1	
Uranium	8.2	--	--	--	--	1	

Appendix E1. Summary statistics for environmental water samples, Sweetwater Arch, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Morrison confining unit	pH (standard units)	7.1	--	7.3	--	7.4	3
	Specific conductance ($\mu\text{S}/\text{cm}$)	640	--	--	--	920	2
	Calcium	63.5	--	77.3	--	77.8	3
	Magnesium	25.6	--	48.3	--	49.0	3
	Sodium	18.5	--	19.0	--	24.0	3
	Potassium	2.7	--	3.9	--	4.1	3
	Alkalinity (as CaCO_3)	169	--	215	--	249	3
	Chloride	4.7	--	6.3	--	7.2	3
	Fluoride	0.17	--	0.20	--	0.21	3
	Silica	4.4	--	5.6	--	6.1	3
	Sulfate	110	--	155	--	185	3
	Total dissolved solids	315	--	445	--	450	3
Sundance aquifer	pH (standard units)	8.0	--	--	--	--	1
	Hardness (as CaCO_3)	180	--	--	--	--	1
	Calcium	40.0	--	--	--	--	1
	Magnesium	20.0	--	--	--	--	1
	Sodium	170	--	--	--	--	1
	Potassium	2.3	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	5.5	--	--	--	--	1
	Alkalinity (as CaCO_3)	210	--	--	--	--	1
	Chloride	7.4	--	--	--	--	1
	Fluoride	0.50	--	--	--	--	1
	Silica	11.0	--	--	--	--	1
	Sulfate	300	--	--	--	--	1
	Total dissolved solids	680	--	--	--	--	1
	Ammonia+organic nitrogen, unfiltered (as N)	0.33	--	--	--	--	1
	Ammonia, unfiltered (as N)	0.11	--	--	--	--	1
	Nitrate+nitrite, unfiltered (as N)	0.040	--	--	--	--	1
	Organic nitrogen, unfiltered (as N)	0.22	--	--	--	--	1
	Total nitrogen, unfiltered (as N)	0.37	--	--	--	--	1
	Phosphorus, unfiltered (as P)	0.010	--	--	--	--	1
	Aluminum	20.0	--	--	--	--	1
	Arsenic	1.0	--	--	--	--	1
	Beryllium	<10.0	--	--	--	--	1
	Boron	200	--	--	--	--	1
	Iron	30.0	--	--	--	--	1
Iron, unfiltered	1,200	--	--	--	--	1	
Lithium	60.0	--	--	--	--	1	
Manganese	<10.0	--	--	--	--	1	
Manganese, unfiltered	30.0	--	--	--	--	1	
Mercury	<0.10	--	--	--	--	1	

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Appendix E1. Summary statistics for environmental water samples, Sweetwater Arch, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Sundance aquifer— Continued	Molybdenum	6.0	--	--	--	--	1
	Selenium	1.0	--	--	--	--	1
	Zinc	<20.0	--	--	--	--	1
Chugwater aquifer and confining unit	Dissolved oxygen	5.0	--	--	--	--	1
	pH (standard units)	7.4	--	7.8	--	7.8	3
	Specific conductance ($\mu\text{S}/\text{cm}$)	447	707	1,710	2,490	2,520	4
	Hardness (as CaCO_3)	220	385	1,080	1,750	1,890	4
	Calcium	57.0	109	310	535	611	4
	Magnesium	20.0	28.5	62.0	101	116	4
	Sodium	7.2	7.9	13.6	31.3	44.0	4
	Potassium	1.4	1.6	2.9	4.1	4.2	4
	Sodium-adsorption ratio (unitless)	0.13	0.16	0.22	0.37	0.48	4
	Alkalinity (as CaCO_3)	95.1	108	153	194	205	4
	Bromide	0.050	--	--	--	--	1
	Chloride	1.4	1.6	3.7	15.8	26.0	4
	Fluoride	0.20	0.20	0.35	0.75	1.0	4
	Silica	8.1	8.6	11.6	15.5	17.0	4
	Sulfate	33.0	194	938	1,530	1,530	4
	Total dissolved solids	264	499	1,500	2,350	2,440	4
	Ammonia (as N)	0.050	--	--	--	--	1
	Nitrate+nitrite (as N)	0.56	--	--	--	--	1
	Nitrite (as N)	<0.008	--	--	--	--	1
	Orthophosphate (as P)	<0.020	--	--	--	--	1
	Aluminum	<1.6	--	--	--	--	1
	Antimony	<0.30	--	--	--	--	1
	Arsenic	1.4	--	--	--	--	1
	Barium	8.0	--	--	--	--	1
	Beryllium	<0.06	--	--	--	--	1
	Boron	--	8.2	78.0	273	400	4
	Cadmium	<0.04	--	--	--	--	1
	Chromium	<0.80	--	--	--	--	1
	Cobalt	1.0	--	--	--	--	1
	Copper	5.1	--	--	--	--	1
	Iron	<24.0	--	--	--	--	1
	Lead	<0.08	--	--	--	--	1
	Lithium	28.0	--	--	--	--	1
Manganese	1.5	--	--	--	--	1	
Molybdenum	6.0	--	--	--	--	1	
Nickel	16.5	--	--	--	--	1	
Selenium	13.3	--	--	--	--	1	
Strontium	8,260	--	--	--	--	1	
Vanadium	3.1	--	--	--	--	1	

Appendix E1. Summary statistics for environmental water samples, Sweetwater Arch, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Chugwater aquifer and confining unit—Continued	Zinc	2.9	--	--	--	--	1
	Radon-222, unfiltered (picocuries per liter)	1,150	--	--	--	--	1
	Uranium	7.6	--	--	--	--	1
Alcova confining unit within Chugwater aquifer and confining unit	pH (standard units)	6.8	--	--	--	7.8	2
	Specific conductance ($\mu\text{S}/\text{cm}$)	627	--	--	--	660	2
	Calcium	48.5	--	--	--	83.9	2
	Magnesium	28.8	--	--	--	45.3	2
	Sodium	16.6	--	--	--	24.7	2
	Potassium	1.2	--	--	--	1.6	2
	Alkalinity (as CaCO_3)	169	--	--	--	211	2
	Chloride	14.3	--	--	--	17.5	2
	Fluoride	0.15	--	--	--	0.17	2
	Silica	5.1	--	--	--	5.1	2
	Sulfate	97.9	--	--	--	179	2
	Total dissolved solids	304	--	--	--	453	2
Goose Egg aquifer and confining unit	Dissolved oxygen	0.60	--	--	--	3.3	2
	pH (standard units)	7.1	7.2	7.7	8.0	8.2	5
	Specific conductance ($\mu\text{S}/\text{cm}$)	1,170	2,230	2,680	3,170	3,220	7
	Hardness (as CaCO_3)	1,440	--	1,870	--	1,940	3
	Calcium	247	402	550	578	598	7
	Magnesium	56.3	76.7	105	121	212	7
	Sodium	11.5	13.7	20.1	154	200	7
	Potassium	1.3	2.6	4.6	6.8	8.4	7
	Sodium-adsorption ratio (unitless)	0.14	--	--	--	1.8	2
	Alkalinity (as CaCO_3)	121	123	138	184	189	7
	Bromide	0.10	--	--	--	0.22	2
	Chloride	3.8	5.6	10.3	35.2	189	7
	Fluoride	0.17	0.19	0.29	0.50	1.3	7
	Silica	4.7	5.7	6.5	11.2	13.2	6
	Sulfate	697	1,280	1,500	1,920	2,040	7
	Total dissolved solids	1,090	2,240	2,430	2,740	3,220	7
	Ammonia (as N)	0.040	--	--	--	0.060	2
	Nitrate (as N)	<0.060	--	--	--	<2.6	2
	Nitrite (as N)	<0.008	--	--	--	<0.008	2
	Orthophosphate (as P)	<0.020	--	--	--	<0.020	2
	Aluminum	<3.2	--	--	--	<3.2	2
	Antimony	<0.60	--	--	--	<0.60	2
Arsenic	0.90	--	--	--	1.9	2	
Barium	8.0	--	--	--	10.0	2	
Beryllium	<0.12	--	--	--	<0.12	2	
Boron	--	135	191	865	865	3	

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Appendix E1. Summary statistics for environmental water samples, Sweetwater Arch, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Goose Egg aquifer and confining unit—Continued	Cadmium	<0.07	--	--	--	<0.07	2
	Chromium	<0.80	--	--	--	<0.80	2
	Cobalt	1.1	--	--	--	2.6	2
	Copper	6.2	--	--	--	8.0	2
	Iron	21.0	--	--	--	47.0	2
	Lead	<0.16	--	--	--	<0.16	2
	Lithium	50.4	--	--	--	75.6	2
	Manganese	24.7	--	--	--	37.8	2
	Molybdenum	5.0	--	--	--	7.5	2
	Nickel	8.3	--	--	--	28.6	2
	Selenium	1.4	--	--	--	11.8	2
	Strontium	4,330	--	--	--	5,190	2
	Vanadium	<0.30	--	--	--	1.1	2
	Zinc	8.2	--	--	--	26.1	2
	Radon-222, unfiltered (picocuries per liter)	280	--	--	--	1,340	2
Uranium	11.5	--	--	--	13.9	2	
Forelle Limestone	pH (standard units)	8.1	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	334	--	--	--	--	1
	Hardness (as CaCO_3)	190	--	--	--	--	1
	Calcium	43.0	--	--	--	--	1
	Magnesium	19.0	--	--	--	--	1
	Sodium	3.8	--	--	--	--	1
	Potassium	0.10	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	0.10	--	--	--	--	1
	Alkalinity (as CaCO_3)	179	--	--	--	--	1
	Chloride	0.70	--	--	--	--	1
	Fluoride	0.10	--	--	--	--	1
	Silica	12.0	--	--	--	--	1
	Sulfate	7.7	--	--	--	--	1
	Total dissolved solids	216	--	--	--	--	1
	Nitrate (as N)	0.70	--	--	--	--	1
Iron, unfiltered	10.0	--	--	--	--	1	
Satanka confining unit	Specific conductance ($\mu\text{S}/\text{cm}$)	1,660	--	--	--	--	1
	Hardness (as CaCO_3)	940	--	--	--	--	1
	Calcium	232	--	--	--	--	1
	Magnesium	88.0	--	--	--	--	1
	Sodium	35.0	--	--	--	--	1
	Potassium	3.0	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	0.50	--	--	--	--	1
	Alkalinity (as CaCO_3)	128	--	--	--	--	1
Chloride	25.0	--	--	--	--	1	

Appendix E1. Summary statistics for environmental water samples, Sweetwater Arch, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Satanka confining unit—Continued	Fluoride	1.0	--	--	--	--	1
	Silica	23.0	--	--	--	--	1
	Sulfate	840	--	--	--	--	1
	Total dissolved solids	1,330	--	--	--	--	1
	Nitrate (as N)	0.84	--	--	--	--	1
	Boron	210	--	--	--	--	1
	Iron, unfiltered	20.0	--	--	--	--	1
Casper aquifer	pH (standard units)	7.6	7.7	8.1	8.1	8.1	6
	Specific conductance ($\mu\text{S}/\text{cm}$)	557	602	680	1,200	2,020	8
	Hardness (as CaCO_3)	233	240	270	404	1,240	7
	Calcium	36.0	56.0	60.0	72.1	394	8
	Magnesium	22.0	23.5	30.9	49.0	62.8	8
	Sodium	5.1	26.5	38.9	46.5	169	8
	Potassium	1.8	2.5	3.2	4.3	11.8	8
	Sodium-adsorption ratio (unitless)	0.67	--	--	--	1.4	2
	Alkalinity (as CaCO_3)	143	160	185	226	251	8
	Chloride	6.2	22.4	39.3	50.1	56.0	8
	Fluoride	0.30	0.50	0.67	1.1	1.3	6
	Silica	10.0	10.5	11.3	17.8	24.0	4
	Sulfate	61.0	97.0	121	362	1,010	8
	Total dissolved solids	276	372	396	820	1,880	8
	Ammonia (as N)	<0.10	--	--	--	<1.0	2
	Nitrate+nitrite (as N)	0.27	--	--	--	1.6	2
	Nitrite (as N)	<0.010	--	--	--	--	1
	Aluminum	<100	--	--	--	--	1
	Boron	--	62.0	184	300	313	7
	Iron, unfiltered	40.0	--	--	--	50.0	2
	Molybdenum	<100	--	--	--	1,000	2
	Nickel	<40.0	--	--	--	--	1
	Gross alpha radioactivity (picocuries per liter)	19.0	--	--	--	--	1
Gross beta radioactivity (picocuries per liter)	10.0	--	--	--	--	1	
Radium-226 (picocuries per liter)	5.6	--	--	--	--	1	
Uranium	41.0	--	--	--	--	1	
Tensleep aquifer	Dissolved oxygen	5.8	--	--	--	--	1
	pH (standard units)	6.5	7.2	7.7	8.0	8.2	17
	Specific conductance ($\mu\text{S}/\text{cm}$)	300	341	427	665	2,360	16
	Hardness (as CaCO_3)	170	180	200	255	1,520	9
	Calcium	47.6	51.1	64.0	98.0	371	16
	Magnesium	11.0	15.0	17.8	35.5	145	16
	Sodium	2.7	3.1	4.0	5.9	170	16

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Appendix E1. Summary statistics for environmental water samples, Sweetwater Arch, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Tensleep aquifer— Continued	Potassium	0.10	0.35	1.1	3.5	10.0	16
	Sodium-adsorption ratio (unitless)	0.080	0.10	0.10	0.13	3.6	9
	Alkalinity (as CaCO_3)	84.0	168	176	201	592	16
	Bromide	0.030	--	--	--	0.040	2
	Chloride	0.70	1.2	5.1	8.0	240	15
	Fluoride	0.090	0.15	0.18	0.20	2.4	16
	Silica	4.1	4.8	8.3	11.5	36.0	16
	Sulfate	6.6	8.4	50.9	200	1,100	16
	Total dissolved solids	165	195	260	450	2,210	16
	Ammonia (as N)	<0.040	--	--	--	0.20	2
	Ammonia+organic nitrogen, unfiltered (as N)	0.21	--	--	--	--	1
	Ammonia, unfiltered (as N)	<0.010	--	--	--	--	1
	Nitrate+nitrite (as N)	<0.060	--	--	--	1.3	2
	Nitrate+nitrite, unfiltered (as N)	0.050	--	--	--	--	1
	Nitrate (as N)	--	0.21	0.36	0.63	0.70	8
	Nitrite (as N)	<0.008	--	--	--	<0.008	2
	Organic nitrogen, unfiltered (as N)	0.21	--	--	--	--	1
	Total nitrogen, unfiltered (as N)	0.26	--	--	--	--	1
	Orthophosphate (as P)	<0.020	--	--	--	<0.020	2
	Phosphorus, unfiltered (as P)	0.010	--	--	--	--	1
	Arsenic	--	0.20	0.20	4.0	4.0	3
	Barium	<0.05	--	--	--	7.0	2
	Boron	--	13.2	70.0	152	180	4
	Cadmium	0.02	--	--	--	0.04	2
	Cobalt	0.18	--	--	--	1.3	2
	Manganese, unfiltered	20.0	--	--	--	--	1
	Mercury	<0.50	--	--	--	--	1
	Nickel	1.7	--	--	--	8.0	2
	Strontium	150	--	--	--	1,620	2
	Iron, unfiltered	--	10.0	40.0	50.0	90.0	7
	Lithium	--	4.8	39.0	120	120	3
	Manganese	--	0.40	20.0	71.9	71.9	3
Vanadium	--	0.30	1.4	3.5	3.5	3	
Radium-226 (picocuries per liter)	0.18	--	--	--	--	1	
Radium-228 (picocuries per liter)	0.03	--	--	--	--	1	
Radon-222, unfiltered (picocuries per liter)	--	120	650	6,080	6,080	3	
Uranium	0.02	--	--	--	2.9	2	
Madison aquifer	Dissolved oxygen	5.5	--	--	--	--	1
	pH (standard units)	7.8	--	--	--	8.3	2
	Specific conductance ($\mu\text{S}/\text{cm}$)	295	--	--	--	406	2

Appendix E1. Summary statistics for environmental water samples, Sweetwater Arch, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Madison aquifer— Continued	Hardness (as CaCO_3)	160	--	--	--	206	2
	Calcium	46.0	--	--	--	55.7	2
	Magnesium	12.0	--	--	--	16.2	2
	Sodium	1.0	--	--	--	3.6	2
	Potassium	0.40	--	--	--	0.61	2
	Sodium-adsorption ratio (unitless)	0.030	--	--	--	0.11	2
	Alkalinity (as CaCO_3)	152	--	--	--	186	2
	Bromide	0.090	--	--	--	--	1
	Chloride	0.60	--	--	--	8.1	2
	Fluoride	0.10	--	--	--	0.17	2
	Silica	6.1	--	--	--	9.1	2
	Sulfate	5.8	--	--	--	15.2	2
	Total dissolved solids	170	--	--	--	233	2
	Ammonia (as N)	<0.040	--	--	--	--	1
	Nitrate+nitrite (as N)	1.7	--	--	--	--	1
	Nitrate (as N)	<1.7	--	--	--	--	1
	Nitrite (as N)	<0.008	--	--	--	--	1
	Aluminum	<1.6	--	--	--	--	1
	Antimony	<0.30	--	--	--	--	1
	Arsenic	0.50	--	--	--	--	1
	Barium	67.0	--	--	--	--	1
	Beryllium	<0.06	--	--	--	--	1
	Boron	9.0	--	--	--	10.0	2
	Cadmium	<0.04	--	--	--	--	1
	Chromium	<0.80	--	--	--	--	1
	Cobalt	0.17	--	--	--	--	1
	Copper	8.2	--	--	--	--	1
	Iron	<8.0	--	--	--	--	1
	Iron, unfiltered	80.0	--	--	--	--	1
	Lead	0.07	--	--	--	--	1
	Lithium	2.9	--	--	--	--	1
	Manganese	<0.20	--	--	--	--	1
	Molybdenum	0.60	--	--	--	--	1
	Nickel	0.71	--	--	--	--	1
	Selenium	1.4	--	--	--	--	1
	Strontium	125	--	--	--	--	1
	Vanadium	2.0	--	--	--	--	1
	Zinc	9.3	--	--	--	--	1
	Radon-222, unfiltered (picocuries per liter)	610	--	--	--	--	1
	Uranium	2.3	--	--	--	--	1

12 Appendix E1

Appendix E1. Summary statistics for environmental water samples, Sweetwater Arch, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Aquifers in undifferentiated Cambrian rocks	pH (standard units)	7.6	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	353	--	--	--	--	1
	Hardness (as CaCO_3)	170	--	--	--	--	1
	Calcium	46.0	--	--	--	--	1
	Magnesium	13.0	--	--	--	--	1
	Sodium	9.3	--	--	--	--	1
	Potassium	1.4	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	0.30	--	--	--	--	1
	Alkalinity (as CaCO_3)	156	--	--	--	--	1
	Chloride	3.0	--	--	--	--	1
	Fluoride	0.10	--	--	--	--	1
	Silica	7.8	--	--	--	--	1
	Sulfate	24.0	--	--	--	--	1
	Total dissolved solids	200	--	--	--	--	1
	Nitrate (as N)	0.25	--	--	--	--	1
	Boron	20.0	--	--	--	--	1
Iron, unfiltered	70.0	--	--	--	--	1	
Flathead aquifer	pH (standard units)	7.1	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	162	--	--	--	--	1
	Hardness (as CaCO_3)	71.0	--	--	--	--	1
	Calcium	21.0	--	--	--	--	1
	Magnesium	4.5	--	--	--	--	1
	Sodium	5.3	--	--	--	--	1
	Potassium	0.90	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	0.27	--	--	--	--	1
	Alkalinity (as CaCO_3)	73.0	--	--	--	--	1
	Chloride	0.10	--	--	--	--	1
	Fluoride	0.20	--	--	--	--	1
	Silica	15.0	--	--	--	--	1
	Sulfate	6.5	--	--	--	--	1
	Total dissolved solids	99.0	--	--	--	--	1
	Nitrate+nitrite (as N)	0.40	--	--	--	--	1
Phosphorus, unfiltered (as P)	0.10	--	--	--	--	1	
Precambrian basal confining unit	Dissolved oxygen	3.9	--	--	--	8.6	2
	pH (standard units)	6.6	6.9	7.0	7.6	8.1	20
	Specific conductance ($\mu\text{S}/\text{cm}$)	50.0	138	212	272	1,100	20
	Hardness (as CaCO_3)	42.0	52.7	101	128	265	12
	Calcium	5.9	13.8	31.0	39.0	70.0	13
	Magnesium	1.5	3.2	4.8	5.8	22.0	13
	Sodium	2.0	5.5	6.8	8.0	130	13
	Potassium	0.33	0.90	1.8	1.9	15.0	13
	Sodium-adsorption ratio (unitless)	0.40	0.30	0.31	0.38	3.5	12

Appendix E1. Summary statistics for environmental water samples, Sweetwater Arch, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Precambrian basal confining unit— Continued	Alkalinity (as CaCO_3)	21.9	58.0	90.0	130	179	13
	Bromide	0.070	--	--	--	--	1
	Chloride	0.10	0.68	0.80	4.3	120	13
	Fluoride	0.070	0.20	0.20	0.30	1.8	13
	Silica	8.0	14.7	17.3	21.0	28.0	13
	Sulfate	0.80	4.8	9.5	17.0	220	13
	Total dissolved solids	34.0	81.0	140	176	714	13
	Nitrate+nitrite (as N)	--	0.20	0.28	0.42	1.2	10
	Phosphorus, unfiltered (as P)	--	0.004	0.008	0.025	0.030	8
	Antimony	0.07	--	--	--	<0.30	2
	Arsenic	--	0.50	1.3	2.5	3.0	4
	Barium	--	17.0	21.0	29.0	51.0	5
	Boron	--	10.0	20.0	40.0	44.0	5
	Copper	--	1.0	1.3	1.5	2.3	5
	Iron	--	10.0	11.0	17.0	100	5
	Iron, unfiltered	<10.0	--	--	--	120	2
	Lithium	--	8.0	14.0	18.8	21.0	5
	Mercury	<0.10	--	--	--	<0.10	2
	Strontium	--	140	140	250	316	5
	Vanadium	--	1.3	1.6	6.0	6.0	3
	Gross alpha radioactivity (picocuries per liter)	25.4	--	--	--	--	1
	Gross beta radioactivity (picocuries per liter)	7.8	--	--	--	--	1
	Radium-228 (picocuries per liter)	2.0	--	--	--	--	1
	Radon-222, unfiltered (picocuries per liter)	2,340	--	--	--	3,790	2
	Tritium, unfiltered (picocuries per liter)	9.0	--	--	--	--	1
	Uranium	1.6	--	--	--	7.1	2

Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Quaternary alluvial aquifers	Dissolved oxygen	0.10	0.10	0.20	3.0	8.2	9
	pH (standard units)	6.5	7.2	7.3	7.8	9.0	26
	Specific conductance ($\mu\text{S}/\text{cm}$)	30.0	440	658	1,100	5,930	35
	Hardness (as CaCO_3)	11.6	150	220	350	2,400	25
	Calcium	3.3	38.0	59.0	103	546	25
	Magnesium	0.82	9.4	15.0	34.0	245	25
	Sodium	1.1	22.0	39.0	84.0	736	25
	Potassium	0.31	1.7	2.8	4.0	20.0	25
	Sodium-adsorption ratio (unitless)	0.11	0.70	0.99	1.8	6.9	25
	Alkalinity (as CaCO_3)	12.0	156	187	243	536	25
	Chloride	0.10	5.5	12.0	33.0	570	25
	Fluoride	0.10	0.30	0.50	0.70	2.8	25
	Silica	0.40	12.0	15.0	19.0	36.0	25
	Sulfate	0.80	41.0	101	232	2,410	25
	Total dissolved solids	28.0	288	394	725	5,840	25
	Ammonia (as N)	--	0.013	0.023	0.050	0.090	10
	Nitrate+nitrite (as N)	--	0.090	0.53	2.4	32.2	11
	Nitrate (as N)	--	0.039	0.20	1.0	35.0	28
	Nitrite (as N)	--	0.001	0.003	0.009	0.58	10
	Orthophosphate (as P)	--	0.008	0.013	0.020	0.070	10
	Aluminum	9.7	--	--	--	--	1
	Antimony	<0.30	--	--	--	--	1
	Arsenic	<0.30	--	--	--	--	1
	Barium	5.0	--	--	--	--	1
	Beryllium	<0.06	--	--	--	--	1
	Boron	--	40.0	100	190	440	19
	Cadmium	<0.04	--	--	--	--	1
	Chromium	<0.80	--	--	--	--	1
	Cobalt	0.04	--	--	--	--	1
	Copper	1.9	--	--	--	--	1
	Iron	32.0	--	--	--	--	1
	Iron, unfiltered	--	130	295	650	1,400	14
	Lead	0.29	--	--	--	--	1
Lithium	<0.50	--	--	--	--	1	
Manganese	0.90	--	--	--	--	1	
Molybdenum	<0.30	--	--	--	--	1	
Nickel	0.38	--	--	--	--	1	
Selenium	<0.50	--	--	--	--	1	
Strontium	12.3	--	--	--	--	1	
Vanadium	0.20	--	--	--	--	1	
Zinc	9.5	--	--	--	--	1	

2 Appendix E2

Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Quaternary alluvial aquifers—Continued	Radon-222, unfiltered (picocuries per liter)	--	781	1,570	2,890	3,570	4
	Uranium	0.06	--	--	--	--	1
Quaternary terrace-deposit aquifers	pH (standard units)	7.5	7.8	7.9	8.1	8.1	5
	Specific conductance ($\mu\text{S}/\text{cm}$)	287	499	714	758	800	4
	Hardness (as CaCO_3)	103	167	174	212	337	5
	Calcium	8.2	28.0	33.0	40.0	73.4	5
	Magnesium	16.0	20.0	25.0	31.0	37.2	5
	Sodium	17.0	43.5	55.0	65.0	80.0	5
	Potassium	0.93	1.2	3.0	3.1	4.4	5
	Sodium-adsorption ratio (unitless)	0.73	1.0	1.8	2.2	2.4	5
	Alkalinity (as CaCO_3)	142	165	180	296	409	5
	Chloride	1.8	8.2	8.9	9.8	11.0	5
	Fluoride	0.70	0.86	0.90	1.2	2.2	5
	Silica	1.0	2.1	7.3	17.2	23.0	5
	Sulfate	20.0	27.0	32.0	171	220	5
	Total dissolved solids	158	360	368	392	512	5
	Ammonia (as N)	<0.010	--	--	--	--	1
	Nitrate+nitrite (as N)	1.5	--	--	--	--	1
	Nitrate (as N)	<1.5	--	--	--	--	1
	Nitrite (as N)	<0.010	--	--	--	--	1
	Orthophosphate (as P)	0.020	--	--	--	--	1
	Boron	--	90.0	100	120	120	3
Radon-222, unfiltered (picocuries per liter)	890	--	--	--	--	1	
Quaternary glacial-deposit aquifers	pH (standard units)	7.1	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	109	--	--	--	--	1
	Hardness (as CaCO_3)	20.0	--	--	--	--	1
	Calcium	7.6	--	--	--	--	1
	Magnesium	0.10	--	--	--	--	1
	Sodium	19.0	--	--	--	--	1
	Potassium	2.2	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	1.9	--	--	--	--	1
	Alkalinity (as CaCO_3)	51.0	--	--	--	--	1
	Chloride	3.5	--	--	--	--	1
	Fluoride	0.30	--	--	--	--	1
	Silica	5.7	--	--	--	--	1
	Sulfate	16.0	--	--	--	--	1
	Total dissolved solids	92.0	--	--	--	--	1
Boron	40.0	--	--	--	--	1	

Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Aquifers in undifferentiated Miocene rocks	pH (standard units)	7.7	--	--	--	9.6	2
	Specific conductance ($\mu\text{S}/\text{cm}$)	420	--	--	--	525	2
	Hardness (as CaCO_3)	4.2	--	--	--	136	2
	Calcium	1.1	--	--	--	43.0	2
	Magnesium	0.35	--	--	--	6.9	2
	Sodium	37.0	--	--	--	110	2
	Potassium	1.6	--	--	--	6.9	2
	Sodium-adsorption ratio (unitless)	1.4	--	--	--	23.4	2
	Alkalinity (as CaCO_3)	150	--	--	--	171	2
	Chloride	14.0	--	--	--	27.0	2
	Fluoride	0.40	--	--	--	2.9	2
	Silica	24.0	--	--	--	45.0	2
	Sulfate	49.0	--	--	--	51.0	2
	Total dissolved solids	306	--	--	--	308	2
	Nitrate+nitrite (as N)	<0.10	--	--	--	0.20	2
Phosphorus, unfiltered (as P)	<0.010	--	--	--	0.040	2	
Browns Park aquifer	Dissolved oxygen	6.6	--	--	--	8.6	2
	pH (standard units)	7.0	7.5	7.7	8.0	9.4	61
	Specific conductance ($\mu\text{S}/\text{cm}$)	214	331	563	1,090	3,410	53
	Hardness (as CaCO_3)	19.0	120	190	310	2,000	50
	Calcium	6.6	36.5	54.5	81.5	646	56
	Magnesium	0.50	4.8	8.2	18.7	147	55
	Sodium	3.3	14.1	38.5	130	453	58
	Potassium	0.80	2.4	4.2	6.9	29.0	54
	Sodium-adsorption ratio (unitless)	0.10	0.45	1.3	4.3	23.0	36
	Alkalinity (as CaCO_3)	34.0	112	150	183	410	57
	Bromide	0.060	--	--	--	0.11	2
	Chloride	0.90	6.0	11.0	77.0	511	57
	Fluoride	0.20	0.45	0.60	1.1	10.8	56
	Silica	4.4	22.0	39.0	50.0	67.7	43
	Sulfate	3.4	23.0	90.0	340	1,980	59
	Total dissolved solids	153	236	385	718	3,410	61
	Ammonia+organic nitrogen, unfiltered (as N)	0.30	--	--	--	--	1
	Ammonia, unfiltered (as N)	0.25	--	--	--	--	1
	Nitrate+nitrite (as N)	--	0.025	0.20	0.70	12.0	11
	Nitrate+nitrite, unfiltered (as N)	<0.10	--	--	--	--	1
	Nitrate (as N)	--	0.019	0.066	0.23	2.3	35
	Organic nitrogen, unfiltered (as N)	0.050	--	--	--	--	1
	Total nitrogen, unfiltered (as N)	0.30	--	--	--	--	1
Orthophosphate (as P)	<0.010	--	--	--	0.030	2	

4 Appendix E2

Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Browns Park aquifer— Continued	Phosphorus (as P)	0.080	--	--	--	--	1
	Phosphorus, unfiltered (as P)	--	0.050	0.060	0.070	0.10	5
	Arsenic	--	1.4	3.0	5.5	21.1	20
	Barium	--	50.7	83.3	137	200	12
	Boron	--	37.0	86.2	290	1,400	36
	Chromium	--	0.82	1.1	1.5	2.0	14
	Cobalt	0.11	--	--	--	0.15	2
	Copper	--	2.4	5.1	10.0	66.0	13
	Iron	--	3.5	13.8	160	310	12
	Iron, unfiltered	--	44.5	120	220	530	16
	Lead	--	0.11	0.32	0.88	4.0	16
	Lithium	--	15.1	35.8	140	140	3
	Manganese	--	4.7	40.0	110	300	15
	Manganese, unfiltered	90.0	--	--	--	--	1
	Molybdenum	--	1.1	4.9	10.0	10.0	3
	Nickel	--	0.75	1.0	1.3	2.0	6
	Selenium	--	0.47	0.81	1.4	5.0	19
	Strontium	285	--	--	--	507	2
	Vanadium	2.4	--	--	--	23.5	2
	Zinc	--	2.5	7.6	20.0	330	13
	Gross alpha radioactivity (picocuries per liter)	--	5.4	8.1	12.4	44.4	12
	Gross beta radioactivity (picocuries per liter)	--	3.3	6.7	11.0	17.2	10
	Radium-226 (picocuries per liter)	--	0.080	0.15	0.30	1.2	9
	Radon-222, unfiltered (picocuries per liter)	--	423	772	1,290	1,670	6
	Tritium, unfiltered (picocuries per liter)	39.4	--	--	--	42.9	2
	Uranium	--	3.0	6.0	16.5	35.8	11
	White River aquifer and confining unit	pH (standard units)	7.9	--	--	--	--
Specific conductance ($\mu\text{S}/\text{cm}$)		370	--	--	--	379	2
Hardness (as CaCO_3)		142	--	--	--	150	2
Calcium		46.0	--	--	--	46.0	2
Magnesium		6.6	--	--	--	8.8	2
Sodium		9.3	--	--	--	23.0	2
Potassium		2.9	--	--	--	3.5	2
Sodium-adsorption ratio (unitless)		0.33	--	--	--	0.84	2
Alkalinity (as CaCO_3)		160	--	--	--	174	2
Chloride		1.1	--	--	--	5.6	2
Fluoride		0.30	--	--	--	0.70	2
Silica		30.0	--	--	--	44.0	2
Sulfate		8.2	--	--	--	15.0	2

Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[-, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
White River aquifer and confining unit—Continued	Total dissolved solids	220	--	--	--	235	2
	Ammonia (as N)	<0.010	--	--	--	--	1
	Nitrate+nitrite (as N)	0.19	--	--	--	--	1
	Nitrate (as N)	0.11	--	--	--	<0.19	2
	Nitrite (as N)	<0.010	--	--	--	--	1
	Orthophosphate (as P)	0.020	--	--	--	--	1
	Phosphorus, unfiltered (as P)	0.060	--	--	--	--	1
	Aluminum	10.0	--	--	--	--	1
	Arsenic	12.0	--	--	--	--	1
	Barium	83.0	--	--	--	--	1
	Beryllium	<0.50	--	--	--	--	1
	Boron	20.0	--	--	--	40.0	2
	Cadmium	2.0	--	--	--	--	1
	Chromium	<1.0	--	--	--	--	1
	Cobalt	<3.0	--	--	--	--	1
	Copper	<1.0	--	--	--	--	1
	Iron	17.0	--	--	--	--	1
	Iron, unfiltered	30.0	--	--	--	--	1
	Lead	<1.0	--	--	--	--	1
	Lithium	19.0	--	--	--	--	1
	Manganese	2.0	--	--	--	--	1
	Mercury	<0.10	--	--	--	--	1
	Selenium	<1.0	--	--	--	--	1
Strontium	300	--	--	--	--	1	
Zinc	5.0	--	--	--	--	1	
Bridger confining unit	pH (standard units)	9.3	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	418	--	--	--	--	1
	Hardness (as CaCO_3)	7.1	--	--	--	--	1
	Calcium	2.1	--	--	--	--	1
	Magnesium	0.44	--	--	--	--	1
	Sodium	87.0	--	--	--	--	1
	Potassium	0.60	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	14.3	--	--	--	--	1
	Alkalinity (as CaCO_3)	123	--	--	--	--	1
	Chloride	3.3	--	--	--	--	1
	Fluoride	0.40	--	--	--	--	1
	Silica	7.6	--	--	--	--	1
	Sulfate	77.0	--	--	--	--	1
	Total dissolved solids	252	--	--	--	--	1
	Ammonia (as N)	<0.010	--	--	--	--	1
Nitrate+nitrite (as N)	<0.050	--	--	--	--	1	
Nitrate (as N)	<0.050	--	--	--	--	1	

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Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Bridger confining unit— Continued	Nitrite (as N)	<0.010	--	--	--	--	1
	Orthophosphate (as P)	0.030	--	--	--	--	1
	Phosphorus, unfiltered (as P)	0.090	--	--	--	--	1
	Aluminum	40.0	--	--	--	--	1
	Arsenic	5.0	--	--	--	--	1
	Barium	24.0	--	--	--	--	1
	Beryllium	<0.50	--	--	--	--	1
	Boron	40.0	--	--	--	--	1
	Cadmium	1.0	--	--	--	--	1
	Chromium	2.0	--	--	--	--	1
	Cobalt	<3.0	--	--	--	--	1
	Copper	<1.0	--	--	--	--	1
	Iron	36.0	--	--	--	--	1
	Lead	2.0	--	--	--	--	1
	Lithium	13.0	--	--	--	--	1
	Manganese	2.0	--	--	--	--	1
	Mercury	<0.10	--	--	--	--	1
	Selenium	<1.0	--	--	--	--	1
	Strontium	31.0	--	--	--	--	1
	Zinc	<3.0	--	--	--	--	1
Laney confining unit (Laney Member of the Green River Formation)	pH (standard units)	7.6	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	900	--	--	--	--	1
	Hardness (as CaCO_3)	180	--	--	--	--	1
	Calcium	40.0	--	--	--	--	1
	Magnesium	20.0	--	--	--	--	1
	Sodium	130	--	--	--	--	1
	Potassium	2.1	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	4.2	--	--	--	--	1
	Alkalinity (as CaCO_3)	267	--	--	--	--	1
	Chloride	3.4	--	--	--	--	1
	Fluoride	0.70	--	--	--	--	1
	Silica	17.0	--	--	--	--	1
	Sulfate	190	--	--	--	--	1
	Total dissolved solids	563	--	--	--	--	1
	Nitrate+nitrite (as N)	0.010	--	--	--	--	1
	Orthophosphate (as P)	0.010	--	--	--	--	1
	Phosphorus (as P)	<0.010	--	--	--	--	1
	Phosphorus, unfiltered (as P)	0.010	--	--	--	--	1
	Boron	50.0	--	--	--	--	1
	Iron	100	--	--	--	--	1
Manganese	20.0	--	--	--	--	1	

Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Crooks Gap Conglomerate	pH (standard units)	6.6	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	106	--	--	--	--	1
	Hardness (as CaCO_3)	41.6	--	--	--	--	1
	Calcium	13.0	--	--	--	--	1
	Magnesium	2.2	--	--	--	--	1
	Sodium	3.9	--	--	--	--	1
	Potassium	0.40	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	0.26	--	--	--	--	1
	Alkalinity (as CaCO_3)	41.0	--	--	--	--	1
	Chloride	0.20	--	--	--	--	1
	Fluoride	0.10	--	--	--	--	1
	Silica	19.0	--	--	--	--	1
	Sulfate	7.9	--	--	--	--	1
	Total dissolved solids	73.0	--	--	--	--	1
	Ammonia (as N)	<0.010	--	--	--	--	1
	Nitrate+nitrite (as N)	0.45	--	--	--	--	1
	Nitrate (as N)	<0.45	--	--	--	--	1
	Nitrite (as N)	<0.010	--	--	--	--	1
	Orthophosphate (as P)	<0.010	--	--	--	--	1
	Phosphorus, unfiltered (as P)	<0.010	--	--	--	--	1
	Aluminum	10.0	--	--	--	--	1
	Arsenic	<1.0	--	--	--	--	1
	Barium	14.0	--	--	--	--	1
	Beryllium	<0.50	--	--	--	--	1
	Boron	<10.0	--	--	--	--	1
	Cadmium	<1.0	--	--	--	--	1
	Chromium	<1.0	--	--	--	--	1
	Cobalt	<3.0	--	--	--	--	1
	Copper	<1.0	--	--	--	--	1
	Iron	20.0	--	--	--	--	1
Lead	<1.0	--	--	--	--	1	
Lithium	5.0	--	--	--	--	1	
Manganese	2.0	--	--	--	--	1	
Mercury	0.10	--	--	--	--	1	
Selenium	<1.0	--	--	--	--	1	
Strontium	74.0	--	--	--	--	1	
Zinc	7.0	--	--	--	--	1	
Uranium	<0.40	--	--	--	--	1	
Battle Spring aquifer	pH (standard units)	7.0	--	--	--	8.0	2
	Specific conductance ($\mu\text{S}/\text{cm}$)	349	--	--	--	359	2
	Hardness (as CaCO_3)	104	--	--	--	113	2
	Calcium	35.0	--	--	--	37.0	2
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Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Battle Spring aquifer-Continued	Magnesium	2.9	--	--	--	6.1	2
	Sodium	9.3	--	--	--	35.0	2
	Potassium	1.1	--	--	--	1.8	2
	Sodium-adsorption ratio (unitless)	0.38	--	--	--	1.5	2
	Alkalinity (as CaCO_3)	94.0	--	--	--	138	2
	Chloride	1.9	--	--	--	4.2	2
	Fluoride	0.10	--	--	--	0.20	2
	Silica	13.0	--	--	--	16.0	2
	Sulfate	36.0	--	--	--	45.0	2
	Total dissolved solids	160	--	--	--	225	2
	Ammonia (as N)	<0.010	--	--	--	0.050	2
	Nitrate+nitrite (as N)	<0.050	--	--	--	0.050	2
	Nitrate (as N)	<0.050	--	--	--	<0.050	2
	Nitrite (as N)	<0.010	--	--	--	<0.010	2
	Orthophosphate (as P)	<0.010	--	--	--	<0.010	2
	Phosphorus, unfiltered (as P)	0.040	--	--	--	0.10	2
	Iron	480	--	--	--	--	1
Manganese	39.0	--	--	--	--	1	
Wind River aquifer	Specific conductance ($\mu\text{S}/\text{cm}$)	530	--	1,630	--	8,370	3
	Hardness (as CaCO_3)	26.0	--	46.0	--	900	3
	Calcium	7.0	--	12.0	--	267	3
	Magnesium	2.1	--	3.9	--	58.0	3
	Sodium	107	--	345	--	1,780	3
	Potassium	0.60	--	2.0	--	4.2	3
	Sodium-adsorption ratio (unitless)	9.1	--	22.1	--	25.7	3
	Alkalinity (as CaCO_3)	98.4	--	164	--	228	3
	Chloride	13.0	--	255	--	894	3
	Fluoride	0.40	--	0.60	--	1.0	3
	Silica	4.9	--	11.0	--	18.0	3
	Sulfate	76.0	--	205	--	3,380	3
	Total dissolved solids	292	--	980	--	6,450	3
	Boron	--	60.0	120	140	140	3
	Iron, unfiltered	--	110	560	940	940	3
Wasatch aquifer	pH (standard units)	7.4	--	--	--	--	1
	Hardness (as CaCO_3)	52.3	--	--	--	--	1
	Calcium	14.0	--	--	--	--	1
	Magnesium	4.2	--	--	--	--	1
	Sodium	22.0	--	--	--	--	1
	Potassium	1.7	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	1.3	--	--	--	--	1
	Alkalinity (as CaCO_3)	89.0	--	--	--	--	1
	Chloride	0.30	--	--	--	--	1

Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Wasatch aquifer— Continued	Fluoride	0.20	--	--	--	--	1
	Silica	19.0	--	--	--	--	1
	Sulfate	11.0	--	--	--	--	1
	Total dissolved solids	126	--	--	--	--	1
	Nitrate+nitrite (as N)	0.10	--	--	--	--	1
	Phosphorus, unfiltered (as P)	<0.010	--	--	--	--	1
Coalmont Formation	Dissolved oxygen	6.7	--	--	--	--	1
	pH (standard units)	6.8	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	162	--	--	--	--	1
	Hardness (as CaCO_3)	65.9	--	--	--	--	1
	Calcium	18.7	--	--	--	--	1
	Magnesium	4.6	--	--	--	--	1
	Sodium	7.1	--	--	--	--	1
	Potassium	0.61	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	0.38	--	--	--	--	1
	Alkalinity (as CaCO_3)	74.0	--	--	--	--	1
	Bromide	0.040	--	--	--	--	1
	Chloride	3.5	--	--	--	--	1
	Fluoride	0.31	--	--	--	--	1
	Silica	46.8	--	--	--	--	1
	Sulfate	3.6	--	--	--	--	1
	Total dissolved solids	136	--	--	--	--	1
	Ammonia (as N)	<0.040	--	--	--	--	1
	Nitrate+nitrite (as N)	0.71	--	--	--	--	1
	Nitrate (as N)	<0.71	--	--	--	--	1
	Nitrite (as N)	<0.008	--	--	--	--	1
	Orthophosphate (as P)	0.080	--	--	--	--	1
	Aluminum	<1.0	--	--	--	--	1
	Antimony	<0.05	--	--	--	--	1
	Arsenic	0.70	--	--	--	--	1
	Barium	94.0	--	--	--	--	1
	Beryllium	<0.06	--	--	--	--	1
	Boron	9.0	--	--	--	--	1
	Cadmium	<0.04	--	--	--	--	1
	Chromium	<0.80	--	--	--	--	1
	Cobalt	0.05	--	--	--	--	1
	Copper	3.5	--	--	--	--	1
	Iron	<10.0	--	--	--	--	1
	Lead	0.10	--	--	--	--	1
Lithium	9.6	--	--	--	--	1	
Manganese	<0.10	--	--	--	--	1	
Molybdenum	0.30	--	--	--	--	1	

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Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Coalmont Formation— Continued	Nickel	0.68	--	--	--	--	1
	Selenium	0.50	--	--	--	--	1
	Strontium	117	--	--	--	--	1
	Vanadium	3.1	--	--	--	--	1
	Zinc	<1.0	--	--	--	--	1
	Gross alpha radioactivity (picocuries per liter)	2.0	--	--	--	--	1
	Gross beta radioactivity (picocuries per liter)	2.0	--	--	--	--	1
	Radium-226 (picocuries per liter)	0.10	--	--	--	--	1
	Radon-222, unfiltered (picocuries per liter)	2,130	--	--	--	--	1
	Uranium	0.18	--	--	--	--	1
Hanna aquifer	pH (standard units)	6.5	7.3	7.9	8.4	10.9	35
	Specific conductance ($\mu\text{S}/\text{cm}$)	67.0	1,140	2,020	3,280	6,200	36
	Hardness (as CaCO_3)	20.0	42.0	73.0	620	3,400	35
	Calcium	2.9	11.0	18.0	150	550	35
	Magnesium	0.50	4.0	8.8	53.0	480	35
	Sodium	3.7	41.0	340	640	1,100	35
	Potassium	0.40	3.2	6.3	9.5	26.0	33
	Sodium-adsorption ratio (unitless)	0.20	0.90	8.4	31.0	78.0	34
	Alkalinity (as CaCO_3)	29.0	170	364	770	1,360	35
	Chloride	0.20	4.9	10.0	29.0	180	35
	Fluoride	0.10	0.30	0.45	1.3	27.0	33
	Silica	0.30	5.6	9.0	14.0	21.0	35
	Sulfate	2.5	74.0	420	1,000	4,300	35
	Total dissolved solids	28.0	645	1,380	1,980	7,500	35
	Ammonia (as N)	1.4	--	--	--	--	1
	Ammonia+organic nitrogen, unfiltered (as N)	--	3.6	4.1	7.4	38.0	9
	Ammonia, unfiltered (as N)	--	2.3	2.7	6.4	34.0	9
	Nitrate+nitrite (as N)	<0.10	--	--	--	--	1
	Nitrate+nitrite, unfiltered (as N)	--	0.014	0.031	0.070	0.41	26
	Nitrate, unfiltered (as N)	--	0.010	0.020	0.050	0.36	10
	Nitrite, unfiltered (as N)	--	0.010	0.010	0.020	0.36	17
	Organic nitrogen, unfiltered (as N)	--	0.25	1.0	1.4	4.0	8
	Total nitrogen, unfiltered (as N)	--	3.6	4.2	7.4	38.0	9
	Phosphorus, unfiltered (as P)	--	0.040	0.16	1.1	11.0	26
	Organic carbon, unfiltered	--	12.0	22.0	50.0	62.0	7
	Aluminum	--	13.1	24.7	46.4	250	22
Antimony	<1.0	--	--	--	2.0	2	
Arsenic	--	0.48	1.0	2.0	13.0	23	

Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Hanna aquifer— Continued	Barium	--	19.9	29.7	44.3	130	5
	Boron	--	40.0	60.0	100	1,500	30
	Chromium	--	1.0	2.7	7.0	60.0	13
	Copper	--	1.6	2.5	6.5	20.0	16
	Iron	--	70.0	120	560	14,000	23
	Iron, unfiltered	--	1,800	5,050	13,000	130,000	26
	Lead	--	1.4	2.2	3.5	9.0	19
	Lithium	--	20.0	60.0	100	180	19
	Manganese	--	40.0	80.0	190	1,300	22
	Manganese, unfiltered	--	70.0	170	610	2,800	21
	Molybdenum	--	1.0	3.0	12.0	32.0	19
	Nickel	--	1.9	2.1	2.4	3.0	17
	Strontium	--	130	160	290	290	3
	Vanadium	--	0.20	0.58	1.7	25.0	11
	Zinc	--	10.9	20.0	58.0	870	21
	Gross beta radioactivity (picocuries per liter)	--	3.7	6.5	12.0	39.0	13
	Radium-226 (picocuries per liter)	--	0.16	0.22	0.35	0.84	13
Uranium	--	0.65	1.9	8.5	14.0	4	
Ferris aquifer	Dissolved oxygen	0.40	--	--	--	0.60	2
	pH (standard units)	6.7	7.1	7.2	7.8	8.7	30
	Specific conductance ($\mu\text{S}/\text{cm}$)	1,550	3,100	3,700	5,500	9,810	29
	Hardness (as CaCO_3)	29.0	690	1,000	1,900	5,200	33
	Calcium	5.7	78.0	180	270	540	33
	Magnesium	3.6	76.0	150	290	960	33
	Sodium	26.0	160	440	660	2,400	33
	Potassium	1.5	5.9	10.0	18.0	110	33
	Sodium-adsorption ratio (unitless)	0.20	1.8	5.8	13.0	44.0	33
	Alkalinity (as CaCO_3)	43.0	458	676	837	1,160	33
	Chloride	5.1	12.0	21.0	43.0	200	33
	Fluoride	0.10	0.20	0.30	0.50	3.1	33
	Silica	0.10	7.4	11.0	13.0	31.0	33
	Sulfate	28.0	870	1,400	2,400	5,200	33
	Total dissolved solids	614	1,930	2,770	4,410	8,240	33
	Ammonia (as N)	4.1	--	--	--	5.0	2
	Ammonia+organic nitrogen, unfiltered (as N)	--	1.4	4.3	5.7	16.0	15
	Ammonia, unfiltered (as N)	--	0.040	2.5	4.2	16.0	15
	Nitrate+nitrite, unfiltered (as N)	--	0.015	0.074	0.22	40.0	35
	Nitrate, unfiltered (as N)	--	0.025	0.075	1.0	40.0	16
Nitrite (as N)	<0.010	--	--	--	<0.010	2	
Nitrite, unfiltered (as N)	--	0.010	0.010	0.035	0.40	20	

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Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Ferris aquifer— Continued	Organic nitrogen, unfiltered (as N)	--	0.20	0.50	1.9	6.1	10
	Total nitrogen, unfiltered (as N)	--	1.7	4.7	6.4	32.0	15
	Orthophosphate (as P)	0.010	--	--	--	0.010	2
	Phosphorus (as P)	0.010	--	--	--	0.050	2
	Phosphorus, unfiltered (as P)	--	0.035	0.20	0.39	4.7	37
	Organic carbon	12.0	--	--	--	16.0	2
	Organic carbon, unfiltered	--	4.6	19.0	20.0	20.0	3
	Aluminum	--	11.5	21.0	38.6	190	28
	Antimony	<1.0	--	--	--	<1.0	2
	Arsenic	--	0.37	0.93	2.5	29.0	28
	Beryllium	--	4.3	6.6	10.0	20.0	26
	Boron	--	100	115	140	1,700	30
	Cadmium	--	0.92	1.3	1.9	5.0	17
	Chromium	--	2.4	5.6	20.0	40.0	18
	Copper	--	2.4	3.9	6.6	20.0	12
	Iron	--	70.0	360	2,600	26,000	30
	Iron, unfiltered	--	4,600	9,650	18,000	47,000	26
	Lead	--	2.3	3.7	5.8	22.0	24
	Lithium	--	40.0	60.0	120	1,000	22
	Manganese	--	55.0	140	375	4,800	28
	Manganese, unfiltered	--	160	310	530	2,000	26
	Molybdenum	--	0.53	1.5	5.0	24.0	26
	Nickel	--	2.0	4.0	8.0	51.0	22
Selenium	--	0.011	0.089	0.71	80.0	26	
Strontium	--	540	6,500	10,000	10,000	3	
Vanadium	--	0.30	0.80	340	360	7	
Zinc	--	16.1	30.0	60.0	5,200	28	
Gross beta radioactivity (picocuries per liter)	--	7.9	11.5	16.9	29.0	8	
Radium-226 (picocuries per liter)	--	0.26	0.50	1.8	2.1	8	
Uranium	--	0.60	1.0	3.3	12.0	7	
Medicine Bow aquifer	pH (standard units)	7.1	--	7.4	--	8.2	3
	Specific conductance ($\mu\text{S}/\text{cm}$)	239	--	560	--	1,640	3
	Hardness (as CaCO_3)	99.0	--	230	--	250	3
	Calcium	26.0	--	45.0	--	84.0	3
	Magnesium	8.0	--	28.0	--	34.0	3
	Sodium	7.4	--	33.0	--	274	3
	Potassium	1.6	--	1.8	--	3.6	3
	Sodium-adsorption ratio (unitless)	0.33	--	1.0	--	6.4	3
	Alkalinity (as CaCO_3)	95.1	--	188	--	220	3
	Chloride	1.2	--	4.4	--	16.0	3

Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Medicine Bow aquifer— Continued	Fluoride	0.30	--	0.50	--	0.60	3
	Silica	6.1	--	8.8	--	11.0	3
	Sulfate	15.0	--	69.0	--	714	3
	Total dissolved solids	119	--	308	--	1,240	3
	Nitrate+nitrite, unfiltered (as N)	0.010	--	--	--	--	1
	Nitrate (as N)	0.068	--	--	--	0.52	2
	Nitrate, unfiltered (as N)	0.010	--	--	--	--	1
	Nitrite, unfiltered (as N)	<0.010	--	--	--	--	1
	Phosphorus, unfiltered (as P)	0.19	--	--	--	--	1
	Aluminum	20.0	--	--	--	--	1
	Arsenic	1.0	--	--	--	--	1
	Beryllium	<10.0	--	--	--	--	1
	Boron	--	20.0	40.0	110	110	3
	Copper	<2.0	--	--	--	--	1
	Iron	2,000	--	--	--	--	1
	Iron, unfiltered	100	--	--	--	40,000	2
	Lead	2.0	--	--	--	--	1
	Lithium	20.0	--	--	--	--	1
	Manganese	240	--	--	--	--	1
	Manganese, unfiltered	330	--	--	--	--	1
	Mercury	<0.10	--	--	--	--	1
	Molybdenum	<1.0	--	--	--	--	1
	Nickel	<2.0	--	--	--	--	1
	Selenium	<1.0	--	--	--	--	1
	Vanadium	0.20	--	--	--	--	1
	Zinc	6.0	--	--	--	--	1
Lewis confining unit	Dissolved oxygen	1.3	--	--	--	2.0	2
	pH (standard units)	7.3	7.4	7.7	8.0	8.0	4
	Specific conductance ($\mu\text{S}/\text{cm}$)	610	1,990	2,120	2,870	8,170	5
	Hardness (as CaCO_3)	98.0	329	655	2,850	4,950	4
	Calcium	21.0	83.5	155	290	416	4
	Magnesium	11.0	29.5	66.0	516	948	4
	Sodium	222	314	448	594	697	4
	Potassium	2.2	3.2	4.7	11.4	17.6	4
	Sodium-adsorption ratio (unitless)	3.5	3.9	6.7	13.5	18.0	4
	Alkalinity (as CaCO_3)	176	235	332	440	510	4
	Bromide	0.48	--	--	--	--	1
	Chloride	9.6	18.8	48.5	83.5	98.0	4
	Fluoride	0.30	0.55	0.87	2.2	3.4	4
	Silica	9.1	10.4	11.8	27.0	42.0	4
	Sulfate	595	818	1,110	3,390	5,590	4
	Total dissolved solids	1,340	1,570	1,990	5,680	9,180	4

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Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Lewis confining unit— Continued	Ammonia (as N)	0.080	--	--	--	0.12	2
	Nitrate+nitrite (as N)	<0.060	--	--	--	0.32	2
	Nitrate (as N)	--	0.040	0.10	0.52	2.3	5
	Nitrite (as N)	<0.008	--	--	--	<0.008	2
	Orthophosphate (as P)	<0.020	--	--	--	<0.020	2
	Aluminum	<3.0	--	--	--	--	1
	Antimony	0.16	--	--	--	--	1
	Arsenic	1.5	--	--	--	--	1
	Barium	5.0	--	--	--	--	1
	Beryllium	<0.20	--	--	--	--	1
	Boron	--	220	350	516	591	4
	Cadmium	<0.10	--	--	--	--	1
	Chromium	<0.80	--	--	--	--	1
	Cobalt	0.79	--	--	--	--	1
	Copper	19.1	--	--	--	--	1
	Iron	<50.0	--	--	--	--	1
	Iron, unfiltered	--	30.0	470	3,700	3,700	3
	Lead	<0.20	--	--	--	--	1
	Lithium	585	--	--	--	--	1
	Manganese	53.2	--	--	--	--	1
	Molybdenum	2.7	--	--	--	--	1
Nickel	6.4	--	--	--	--	1	
Selenium	8.5	--	--	--	--	1	
Strontium	6,820	--	--	--	--	1	
Vanadium	3.3	--	--	--	--	1	
Zinc	10.9	--	--	--	--	1	
Radon-222, unfiltered (picocuries per liter)	450	--	--	--	--	1	
Uranium	42.7	--	--	--	--	1	
Mesaverde aquifer	Dissolved oxygen	0.10	0.20	0.30	0.50	1.0	6
	pH (standard units)	6.1	6.9	7.3	7.7	8.2	12
	Specific conductance ($\mu\text{S}/\text{cm}$)	302	1,040	1,430	1,850	5,390	17
	Hardness (as CaCO_3)	25.0	240	440	617	2,200	17
	Calcium	5.8	52.0	104	152	417	17
	Magnesium	2.6	24.0	41.0	66.1	271	17
	Sodium	12.0	54.0	100	337	691	17
	Potassium	1.0	2.6	3.3	4.8	7.1	17
	Sodium-adsorption ratio (unitless)	0.30	0.83	1.8	7.0	29.0	17
	Alkalinity (as CaCO_3)	52.5	184	269	336	738	17
	Bromide	0.040	0.040	0.060	0.070	0.070	6
	Chloride	0.10	6.1	10.0	20.0	93.0	17
	Fluoride	0.11	0.46	0.51	0.60	3.2	17

Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Mesaverde aquifer— Continued	Silica	8.4	11.0	13.4	17.0	26.0	17
	Sulfate	5.0	253	375	703	3,430	17
	Total dissolved solids	181	724	974	1,440	5,200	17
	Ammonia (as N)	--	0.048	0.17	0.27	0.61	6
	Ammonia+organic nitrogen, unfiltered (as N)	0.47	--	--	--	--	1
	Ammonia, unfiltered (as N)	0.38	--	--	--	--	1
	Nitrate+nitrite, unfiltered (as N)	<0.10	--	--	--	--	1
	Nitrate (as N)	--	0.005	0.019	0.071	1.2	17
	Organic nitrogen, unfiltered (as N)	0.090	--	--	--	--	1
	Total nitrogen, unfiltered (as N)	0.47	--	--	--	--	1
	Phosphorus, unfiltered (as P)	0.020	--	--	--	--	1
	Arsenic	--	0.16	0.26	0.42	0.80	7
	Barium	--	8.0	17.0	23.0	110	6
	Boron	--	60.0	100	170	390	17
	Cadmium	--	0.002	0.019	0.42	3.0	7
	Cobalt	--	0.22	0.40	0.67	1.1	6
	Copper	--	1.3	1.9	2.8	4.4	7
	Iron	--	32.0	1,510	4,760	5,140	7
	Iron, unfiltered	--	130	1,300	1,700	8,900	11
	Lead	--	0.12	0.49	1.4	3.0	7
	Lithium	--	16.9	32.9	84.9	87.0	7
	Manganese	--	23.8	27.0	382	600	7
	Manganese, unfiltered	610	--	--	--	--	1
	Mercury	<0.10	--	--	--	--	1
	Molybdenum	--	0.26	0.47	1.5	1.5	7
	Nickel	--	0.93	2.2	2.4	4.0	7
	Selenium	--	0.35	0.47	0.63	0.80	7
	Strontium	--	962	1,330	1,510	4,910	6
	Vanadium	--	1.0	1.4	2.2	2.6	6
	Zinc	--	9.4	96.1	521	4,030	7
	Gross beta radioactivity (picocuries per liter)	7.3	--	--	--	--	1
Radium-226 (picocuries per liter)	0.55	--	--	--	--	1	
Radon-222, unfiltered (picocuries per liter)	--	180	700	1,260	1,490	6	
Uranium	--	0.33	0.97	3.5	6.2	7	
Cody confining unit	pH (standard units)	7.3	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	6,020	--	--	--	--	1
	Hardness (as CaCO_3)	1,300	--	--	--	--	1
	Calcium	201	--	--	--	--	1

Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Cody confining unit— Continued	Magnesium	192	--	--	--	--	1
	Sodium	1,070	--	--	--	--	1
	Potassium	7.6	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	13.0	--	--	--	--	1
	Alkalinity (as CaCO_3)	474	--	--	--	--	1
	Chloride	70.0	--	--	--	--	1
	Fluoride	2.0	--	--	--	--	1
	Silica	8.5	--	--	--	--	1
	Sulfate	3,080	--	--	--	--	1
	Total dissolved solids	5,110	--	--	--	--	1
	Nitrate (as N)	<0.023	--	--	--	--	1
	Iron, unfiltered	<10.0	--	--	--	--	1
Steele confining unit	Dissolved oxygen	0.10	--	4.2	--	4.9	3
	pH (standard units)	7.2	7.4	7.7	7.8	7.8	5
	Specific conductance ($\mu\text{S}/\text{cm}$)	302	1,080	4,010	6,090	18,000	8
	Hardness (as CaCO_3)	86.0	130	310	2,180	4,520	7
	Calcium	12.0	35.0	49.0	295	366	7
	Magnesium	11.0	12.0	45.0	348	873	7
	Sodium	8.8	45.0	1,040	1,220	3,500	7
	Potassium	1.0	2.0	4.1	10.8	13.2	7
	Sodium-adsorption ratio (unitless)	0.33	1.7	9.7	30.3	53.5	7
	Alkalinity (as CaCO_3)	150	175	351	748	899	7
	Bromide	0.030	--	0.22	--	3.6	3
	Chloride	0.98	11.0	29.5	470	659	7
	Fluoride	0.12	0.30	0.51	1.3	1.3	7
	Silica	6.0	7.9	9.6	13.1	16.0	7
	Sulfate	12.9	44.0	1,700	3,920	10,600	7
	Total dissolved solids	175	272	3,420	6,440	17,900	7
	Ammonia (as N)	--	0.63	1.6	3.6	5.1	4
	Nitrate+nitrite (as N)	--	0.040	0.10	5.6	11.0	4
	Nitrate (as N)	--	0.093	0.17	1.6	10.9	8
	Nitrite (as N)	--	0.008	0.019	0.066	0.10	4
	Antimony	--	0.040	0.080	37.8	37.8	3
	Arsenic	--	0.40	0.90	22.6	22.6	3
	Barium	--	4.0	70.0	121	121	3
	Boron	--	90.0	570	1,040	2,300	7
	Cobalt	--	0.068	0.54	55.5	55.5	3
	Copper	--	11.5	13.7	165	165	3
Iron, unfiltered	--	110	520	6,700	6,700	3	
Lithium	--	7.1	606	3,200	3,200	3	
Manganese	--	10.5	261	15,600	15,600	3	
Molybdenum	--	0.50	1.8	222	222	3	

Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Steele confining unit— Continued	Strontium	--	329	6,410	13,300	13,300	3
	Vanadium	--	0.10	3.5	64.5	64.5	3
	Zinc	--	9.4	19.7	89.8	89.8	3
	Radon-222, unfiltered (picocuries per liter)	--	70.0	140	1,090	1,090	3
	Uranium	--	0.080	3.8	349	349	3
Niobrara confining unit	Dissolved oxygen	0.10	--	--	--	--	1
	pH (standard units)	7.0	--	7.5	--	8.0	3
	Specific conductance ($\mu\text{S}/\text{cm}$)	1,030	1,560	2,850	3,350	3,670	5
	Hardness (as CaCO_3)	170	240	447	892	1,200	4
	Calcium	43.0	59.5	97.0	198	278	4
	Magnesium	16.0	23.0	50.3	96.3	122	4
	Sodium	118	199	345	428	446	4
	Potassium	2.6	3.5	4.6	6.3	7.8	4
	Sodium-adsorption ratio (unitless)	2.9	4.0	6.6	8.6	9.2	4
	Alkalinity (as CaCO_3)	300	307	332	358	367	4
	Chloride	50.0	69.3	139	192	194	4
	Fluoride	0.36	0.58	0.85	0.90	0.90	4
	Silica	9.5	11.0	12.7	13.5	14.0	4
	Sulfate	133	159	657	1,280	1,420	4
	Total dissolved solids	679	816	1,510	2,510	2,950	4
	Ammonia (as N)	0.27	--	--	--	2.4	2
	Nitrate+nitrite (as N)	<0.060	--	--	--	0.58	2
	Nitrite (as N)	<0.008	--	--	--	<0.010	2
	Orthophosphate (as P)	<0.010	--	--	--	<0.020	2
	Boron	--	510	770	940	940	3
Iron, unfiltered	40.0	--	--	--	50.0	2	
Radon-222, unfiltered (picocuries per liter)	410	--	--	--	--	1	
Frontier aquifer	Specific conductance ($\mu\text{S}/\text{cm}$)	610	--	--	--	--	1
	Hardness (as CaCO_3)	18.0	--	--	--	--	1
	Calcium	4.4	--	--	--	--	1
	Magnesium	1.7	--	--	--	--	1
	Sodium	137	--	--	--	--	1
	Potassium	1.2	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	14.1	--	--	--	--	1
	Alkalinity (as CaCO_3)	268	--	--	--	--	1
	Chloride	7.5	--	--	--	--	1
	Fluoride	1.6	--	--	--	--	1
	Silica	6.9	--	--	--	--	1
	Sulfate	36.0	--	--	--	--	1
	Total dissolved solids	358	--	--	--	--	1

Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Frontier aquifer— Continued	Nitrate (as N)	0.045	--	--	--	--	1
	Boron	600	--	--	--	--	1
Cloverly aquifer	pH (standard units)	7.3	7.6	8.1	9.4	9.5	7
	Specific conductance ($\mu\text{S}/\text{cm}$)	301	361	595	2,670	6,260	8
	Hardness (as CaCO_3)	2.0	5.8	25.0	66.0	470	8
	Calcium	1.0	1.5	5.0	17.0	126	7
	Magnesium	0.10	0.40	2.0	15.0	37.0	7
	Sodium	65.0	69.0	96.0	220	1,600	9
	Potassium	0.10	0.70	2.3	6.0	8.4	8
	Sodium-adsorption ratio (unitless)	7.7	15.5	41.0	55.0	68.0	5
	Alkalinity (as CaCO_3)	78.7	142	190	297	1,250	9
	Bromide	1.0	--	--	--	--	1
	Chloride	1.0	3.0	3.5	7.1	1,140	9
	Fluoride	0.50	0.72	1.1	2.1	4.2	8
	Silica	10.0	11.0	16.0	23.0	32.0	9
	Sulfate	1.5	24.0	30.0	85.0	1,090	9
	Total dissolved solids	188	219	282	557	4,480	9
	Nitrate+nitrite (as N)	<0.10	--	--	--	--	1
	Nitrite (as N)	<0.010	--	--	--	--	1
	Antimony	<1.0	--	--	--	--	1
	Arsenic	<4.0	--	--	--	<5.0	2
	Barium	23.0	--	--	--	<100	2
	Beryllium	5.0	--	--	--	--	1
	Boron	--	39.4	145	380	900	8
	Cadmium	<0.50	--	--	--	<10.0	2
	Chromium	<50.0	--	--	--	<50.0	2
	Copper	<10.0	--	--	--	<10.0	2
	Iron	90.0	--	--	--	320	2
	Iron, unfiltered	--	110	300	520	1,000	7
	Lead	<1.0	--	--	--	<50.0	2
	Manganese	<10.0	--	--	--	45.0	2
	Mercury	<0.50	--	--	--	0.60	2
	Nickel	<20.0	--	--	--	--	1
	Selenium	<4.0	--	--	--	<5.0	2
	Zinc	<10.0	--	--	--	10.0	2
	Gross alpha radioactivity (picocuries per liter)	1.8	--	--	--	--	1
Gross beta radioactivity (picocuries per liter)	1.1	--	--	--	3.3	2	
Radium-226 (picocuries per liter)	0.40	--	--	--	1.3	2	
Radium-228 (picocuries per liter)	<1.0	--	--	--	1.0	2	
Uranium	<0.30	--	--	--	--	1	

Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Sundance aquifer	pH (standard units)	8.5	--	--	--	8.6	2
	Specific conductance ($\mu\text{S}/\text{cm}$)	1,750	--	2,620	--	2,870	3
	Hardness (as CaCO_3)	5.0	--	6.0	--	590	3
	Calcium	1.0	--	2.0	--	156	3
	Magnesium	0.10	--	0.90	--	49.0	3
	Sodium	378	--	460	--	746	3
	Potassium	1.6	--	4.2	--	5.7	3
	Sodium-adsorption ratio (unitless)	6.8	--	90.0	--	130	3
	Alkalinity (as CaCO_3)	64.8	--	934	--	971	3
	Chloride	26.0	--	39.0	--	187	3
	Fluoride	1.0	--	--	--	6.8	2
	Silica	7.4	--	11.0	--	30.0	3
	Sulfate	1.0	--	302	--	1,280	3
	Total dissolved solids	1,100	--	1,910	--	2,010	3
	Boron	--	180	450	3,600	3,600	3
	Iron, unfiltered	--	30.0	170	4,200	4,200	3
Nugget aquifer	pH (standard units)	8.7	8.8	8.8	8.9	8.9	4
	Specific conductance ($\mu\text{S}/\text{cm}$)	923	962	1,030	1,055	1,060	4
	Hardness (as CaCO_3)	9.0	9.0	9.0	16.5	24.0	4
	Calcium	2.0	2.0	2.0	3.0	4.0	4
	Magnesium	1.0	1.0	1.0	2.0	3.0	4
	Sodium	249	252	257	267	273	4
	Potassium	2.0	--	2.0	--	2.0	3
	Alkalinity (as CaCO_3)	360	375	400	415	420	4
	Chloride	3.0	4.5	6.5	7.5	8.0	4
	Fluoride	0.80	0.90	1.1	1.4	1.6	4
	Silica	1.5	--	9.8	--	11.9	3
	Sulfate	160	160	162	167	170	4
	Total dissolved solids	596	622	673	806	913	4
	Boron	--	300	400	400	400	3
	Molybdenum	20.0	--	--	--	--	1
	Gross alpha radioactivity (picocuries per liter)	10.0	--	--	--	10.8	2
Uranium	<1.0	--	--	--	10.0	2	
Chugwater aquifer and confining unit	Specific conductance ($\mu\text{S}/\text{cm}$)	708	--	--	--	--	1
	Hardness (as CaCO_3)	230	--	--	--	--	1
	Calcium	53.0	--	--	--	--	1
	Magnesium	25.0	--	--	--	--	1
	Sodium	56.0	--	--	--	--	1
	Potassium	3.6	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	1.6	--	--	--	--	1
	Alkalinity (as CaCO_3)	163	--	--	--	--	1

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Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Chugwater aquifer and confining unit—Continued	Chloride	9.9	--	--	--	--	1
	Fluoride	0.50	--	--	--	--	1
	Silica	11.0	--	--	--	--	1
	Sulfate	175	--	--	--	--	1
	Total dissolved solids	442	--	--	--	--	1
	Nitrate (as N)	1.7	--	--	--	--	1
	Boron	140	--	--	--	--	1
Satanka confining unit	Specific conductance ($\mu\text{S}/\text{cm}$)	1,780	--	--	--	--	1
	Hardness (as CaCO_3)	900	--	--	--	--	1
	Calcium	148	--	--	--	--	1
	Magnesium	128	--	--	--	--	1
	Sodium	110	--	--	--	--	1
	Alkalinity (as CaCO_3)	384	--	--	--	--	1
	Chloride	23.0	--	--	--	--	1
	Fluoride	1.5	--	--	--	--	1
	Sulfate	667	--	--	--	--	1
	Total dissolved solids	1,330	--	--	--	--	1
	Nitrate (as N)	0.045	--	--	--	--	1
	Boron	180	--	--	--	--	1
Casper aquifer	pH (standard units)	7.0	--	7.5	--	7.7	3
	Specific conductance ($\mu\text{S}/\text{cm}$)	589	--	3,780	--	13,800	3
	Hardness (as CaCO_3)	205	--	1,100	--	1,800	3
	Calcium	45.0	--	378	--	630	3
	Magnesium	22.0	--	43.0	--	43.0	3
	Sodium	32.0	--	448	--	2,740	3
	Potassium	1.9	--	16.6	--	75.0	3
	Sodium-adsorption ratio (unitless)	5.8	--	--	--	28.5	2
	Alkalinity (as CaCO_3)	96.7	--	149	--	166	3
	Chloride	50.0	--	350	--	3,720	3
	Fluoride	0.30	--	2.9	--	3.9	3
	Silica	16.0	--	26.0	--	37.0	3
	Sulfate	35.0	--	1,590	--	2,160	3
	Total dissolved solids	340	--	3,060	--	9,650	3
	Nitrate (as N)	0.023	--	--	--	0.25	2
	Boron	--	100	360	650	650	3
	Iron	10.0	--	--	--	--	1
	Iron, unfiltered	1,300	--	--	--	--	1
Tensleep aquifer	pH (standard units)	8.0	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	499	--	--	--	--	1
	Hardness (as CaCO_3)	200	--	--	--	270	2
	Calcium	48.0	--	--	--	60.0	2
	Magnesium	20.0	--	--	--	29.0	2

Appendix E2. Summary statistics for environmental water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Tensleep aquifer— Continued	Sodium	21.0	--	--	--	180	2
	Potassium	3.8	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	0.64	--	--	--	--	1
	Alkalinity (as CaCO_3)	161	--	--	--	180	2
	Chloride	17.0	--	--	--	58.0	2
	Fluoride	0.60	--	--	--	2.7	2
	Silica	9.2	--	--	--	--	1
	Sulfate	60.0	--	--	--	460	2
	Total dissolved solids	276	--	--	--	950	2
	Nitrate (as N)	0.023	--	--	--	0.050	2
	Arsenic	13.0	--	--	--	--	1
	Barium	1.0	--	--	--	--	1
	Boron	80.0	--	--	--	--	1
	Copper	70.0	--	--	--	--	1
	Iron	600	--	--	--	--	1
	Iron, unfiltered	30.0	--	--	--	--	1
	Manganese	10.0	--	--	--	--	1
	Zinc	160	--	--	--	--	1
	Gross alpha radioactivity (picocuries per liter)	17.0	--	--	--	--	1
	Precambrian basal confining unit	pH (standard units)	7.1	--	--	--	7.1
Specific conductance ($\mu\text{S}/\text{cm}$)		244	--	--	--	280	2
Hardness (as CaCO_3)		84.7	--	--	--	--	1
Calcium		26.0	--	--	--	--	1
Magnesium		4.8	--	--	--	--	1
Sodium		17.0	--	--	--	--	1
Potassium		3.3	--	--	--	--	1
Sodium-adsorption ratio (unitless)		0.80	--	--	--	--	1
Alkalinity (as CaCO_3)		113	--	--	--	--	1
Chloride		9.2	--	--	--	--	1
Fluoride		0.50	--	--	--	--	1
Silica		38.0	--	--	--	--	1
Sulfate		13.0	--	--	--	--	1
Total dissolved solids		181	--	--	--	--	1
Nitrate+nitrite (as N)		0.30	--	--	--	--	1
Phosphorus, unfiltered (as P)		0.020	--	--	--	--	1

Appendix E3. Summary statistics for environmental water samples, Sierra Madre, Wyoming.

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Frontier aquifer	pH (standard units)	9.3	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	1,170	--	--	--	--	1
	Hardness (as CaCO_3)	19.0	--	--	--	--	1
	Calcium	5.5	--	--	--	--	1
	Magnesium	1.3	--	--	--	--	1
	Sodium	290	--	--	--	--	1
	Potassium	1.0	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	29.0	--	--	--	--	1
	Alkalinity (as CaCO_3)	604	--	--	--	--	1
	Chloride	6.5	--	--	--	--	1
	Fluoride	1.2	--	--	--	--	1
	Silica	7.8	--	--	--	--	1
	Sulfate	37.0	--	--	--	--	1
	Total dissolved solids	714	--	--	--	--	1
	Nitrate (as N)	<0.010	--	--	--	--	1
	Boron	370	--	--	--	--	1
	Iron, unfiltered	690	--	--	--	--	1
Precambrian basal confining unit	Dissolved oxygen	7.2	--	--	--	--	1
	pH (standard units)	7.8	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	311	--	--	--	--	1
	Hardness (as CaCO_3)	117	--	--	--	--	1
	Calcium	37.1	--	--	--	--	1
	Magnesium	5.9	--	--	--	--	1
	Sodium	18.7	--	--	--	--	1
	Potassium	1.6	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	0.75	--	--	--	--	1
	Alkalinity (as CaCO_3)	139	--	--	--	--	1
	Bromide	0.090	--	--	--	--	1
	Chloride	5.7	--	--	--	--	1
	Fluoride	1.8	--	--	--	--	1
	Silica	20.0	--	--	--	--	1
	Sulfate	10.6	--	--	--	--	1
	Total dissolved solids	186	--	--	--	--	1
	Ammonia (as N)	<0.040	--	--	--	--	1
	Nitrate+nitrite (as N)	0.90	--	--	--	--	1
	Nitrate (as N)	<0.90	--	--	--	--	1
	Nitrite (as N)	<0.008	--	--	--	--	1
	Orthophosphate (as P)	0.010	--	--	--	--	1
	Aluminum	<1.0	--	--	--	--	1
Antimony	0.04	--	--	--	--	1	

2 Appendix E3

Appendix E3. Summary statistics for environmental water samples, Sierra Madre, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Precambrian basal confining unit— Continued	Arsenic	13.0	--	--	--	--	1
	Barium	11.0	--	--	--	--	1
	Beryllium	<0.06	--	--	--	--	1
	Boron	35.0	--	--	--	--	1
	Cadmium	<0.04	--	--	--	--	1
	Chromium	<0.80	--	--	--	--	1
	Cobalt	0.08	--	--	--	--	1
	Copper	0.40	--	--	--	--	1
	Iron	<10.0	--	--	--	--	1
	Lead	<0.08	--	--	--	--	1
	Lithium	55.9	--	--	--	--	1
	Manganese	<0.10	--	--	--	--	1
	Molybdenum	2.0	--	--	--	--	1
	Nickel	<0.06	--	--	--	--	1
	Selenium	1.0	--	--	--	--	1
	Strontium	383	--	--	--	--	1
	Vanadium	2.4	--	--	--	--	1
	Zinc	1.8	--	--	--	--	1
	Gross alpha radioactivity (picocuries per liter)	45.9	--	--	--	--	1
	Gross beta radioactivity (picocuries per liter)	11.0	--	--	--	--	1
	Radium-228 (picocuries per liter)	2.0	--	--	--	--	1
	Radon-222, unfiltered (picocuries per liter)	4,120	--	--	--	--	1
	Tritium, unfiltered (picocuries per liter)	2.9	--	--	--	--	1
	Uranium	12.8	--	--	--	--	1

Appendix E4. Summary statistics for environmental water samples, Medicine Bow Mountains, Wyoming.

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Quaternary alluvial aquifers	Specific conductance ($\mu\text{S}/\text{cm}$)	261	--	--	--	--	1
	Hardness (as CaCO_3)	130	--	--	--	--	1
	Calcium	38.0	--	--	--	--	1
	Magnesium	7.5	--	--	--	--	1
	Sodium	6.2	--	--	--	--	1
	Potassium	1.9	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	0.24	--	--	--	--	1
	Alkalinity (as CaCO_3)	136	--	--	--	--	1
	Chloride	3.1	--	--	--	--	1
	Fluoride	0.10	--	--	--	--	1
	Silica	16.0	--	--	--	--	1
	Sulfate	6.0	--	--	--	--	1
	Total dissolved solids	161	--	--	--	--	1
	Nitrate (as N)	0.023	--	--	--	--	1
	Boron	<10.0	--	--	--	--	1
Aquifers in Quaternary glacial deposits	Specific conductance ($\mu\text{S}/\text{cm}$)	57.0	--	--	--	--	1
	Hardness (as CaCO_3)	22.0	--	--	--	--	1
	Calcium	8.4	--	--	--	--	1
	Magnesium	0.20	--	--	--	--	1
	Sodium	0.50	--	--	--	--	1
	Potassium	0.40	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	0.050	--	--	--	--	1
	Alkalinity (as CaCO_3)	22.1	--	--	--	--	1
	Chloride	0.70	--	--	--	--	1
	Silica	3.6	--	--	--	--	1
	Sulfate	0.40	--	--	--	--	1
	Total dissolved solids	44.0	--	--	--	--	1
	Nitrate (as N)	0.25	--	--	--	--	1
	Boron	<10.0	--	--	--	--	1
	Iron, unfiltered	260	--	--	--	--	1
Browns Park aquifer	Dissolved oxygen	8.8	--	--	--	--	1
	pH (standard units)	6.1	7.0	8.0	8.1	8.4	6
	Specific conductance ($\mu\text{S}/\text{cm}$)	77.0	144	186	192	364	6
	Hardness (as CaCO_3)	32.8	--	--	--	45.7	2
	Calcium	9.6	15.0	20.5	30.0	69.0	6
	Magnesium	1.4	2.1	3.9	4.2	5.0	6
	Sodium	2.2	4.3	5.7	7.7	10.0	6
	Potassium	0.47	0.50	1.2	1.7	1.8	6
	Sodium-adsorption ratio (unitless)	0.16	--	--	--	--	1
	Alkalinity (as CaCO_3)	37.0	64.0	80.8	100	190	6
	Bromide	0.030	--	--	--	--	1

2 Appendix E4

Appendix E4. Summary statistics for environmental water samples, Medicine Bow Mountains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Browns Park aquifer— Continued	Chloride	0.10	0.43	1.0	1.2	3.0	6
	Fluoride	0.10	--	--	--	0.22	2
	Silica	9.5	--	--	--	14.1	2
	Sulfate	1.8	3.0	3.0	4.3	9.9	6
	Total dissolved solids	45.0	100	115	125	220	6
	Ammonia (as N)	<0.040	--	--	--	--	1
	Nitrate+nitrite (as N)	0.17	--	--	--	--	1
	Nitrite (as N)	<0.008	--	--	--	<0.10	2
	Orthophosphate (as P)	<0.020	--	--	--	--	1
	Aluminum	2.0	--	--	--	--	1
	Antimony	<0.05	--	--	--	3.0	2
	Arsenic	0.10	--	--	--	3.0	2
	Barium	22.0	--	--	--	<100	2
	Beryllium	<0.06	--	--	--	1.0	2
	Cadmium	0.04	--	--	--	<0.50	2
	Chromium	0.80	--	--	--	<50.0	2
	Cobalt	0.04	--	--	--	--	1
	Copper	1.7	--	--	--	4,280	2
	Iron	<10.0	--	--	--	1,340	2
	Lead	0.29	--	--	--	200	2
	Lithium	0.30	--	--	--	--	1
	Manganese	0.20	--	--	--	30.0	2
	Mercury	<0.20	--	--	--	--	1
	Molybdenum	<0.20	--	--	--	--	1
	Nickel	0.74	--	--	--	80.0	2
	Selenium	<0.30	--	--	--	<1.0	2
	Strontium	35.3	--	--	--	--	1
	Vanadium	0.70	--	--	--	--	1
	Zinc	49.2	--	--	--	130	2
	Gross alpha radioactivity (picocuries per liter)	<1.0	--	--	--	--	1
	Gross beta radioactivity (picocuries per liter)	<1.0	--	--	--	--	1
	Radium-226 (picocuries per liter)	<0.20	--	--	--	--	1
	Radium-228 (picocuries per liter)	<1.0	--	--	--	--	1
Radon-222, unfiltered (picocuries per liter)	1,030	--	--	--	--	1	
Uranium	0.05	--	--	--	10.0	2	
Frontier aquifer	pH (standard units)	6.8	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	332	--	--	--	--	1
	Hardness (as CaCO_3)	121	--	--	--	--	1
	Calcium	28.0	--	--	--	--	1
	Magnesium	12.3	--	--	--	--	1

Appendix E4. Summary statistics for environmental water samples, Medicine Bow Mountains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Frontier aquifer— Continued	Sodium	17.1	--	--	--	--	1
	Potassium	1.7	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	0.68	--	--	--	--	1
	Alkalinity (as CaCO_3)	87.0	--	--	--	--	1
	Chloride	9.3	--	--	--	--	1
	Fluoride	0.53	--	--	--	--	1
	Silica	10.2	--	--	--	--	1
	Sulfate	48.5	--	--	--	--	1
	Total dissolved solids	192	--	--	--	--	1
	Ammonia (as N)	0.030	--	--	--	--	1
	Nitrate+nitrite (as N)	2.8	--	--	--	--	1
	Nitrate (as N)	2.8	--	--	--	--	1
	Nitrite (as N)	0.014	--	--	--	--	1
	Orthophosphate (as P)	<0.010	--	--	--	--	1
Cloverly aquifer	pH (standard units)	7.7	--	--	--	8.1	2
	Specific conductance ($\mu\text{S}/\text{cm}$)	158	--	251	--	279	3
	Hardness (as CaCO_3)	94.4	--	--	--	120	2
	Calcium	24.8	--	38.0	--	42.0	3
	Magnesium	2.3	--	5.1	--	8.2	3
	Sodium	2.2	--	6.0	--	7.3	3
	Potassium	1.1	--	--	--	1.4	2
	Sodium-adsorption ratio (unitless)	0.24	--	--	--	--	1
	Alkalinity (as CaCO_3)	91.0	--	121	--	170	3
	Chloride	0.90	--	1.3	--	2.0	3
	Fluoride	0.40	--	--	--	--	1
	Silica	26.0	--	--	--	--	1
	Sulfate	7.3	--	7.4	--	10.0	3
	Total dissolved solids	112	--	168	--	168	3
	Nitrate (as N)	0.023	--	--	--	0.15	2
	Boron	10.0	--	--	--	--	1
	Iron	<60.0	--	--	--	--	1
Iron, unfiltered	90.0	--	--	--	--	1	
Jelm aquifer	pH (standard units)	8.4	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	713	--	--	--	--	1
	Calcium	94.0	--	--	--	--	1
	Magnesium	37.0	--	--	--	--	1
	Sodium	11.0	--	--	--	--	1
	Potassium	1.2	--	--	--	--	1
	Alkalinity (as CaCO_3)	240	--	--	--	--	1
	Chloride	1.6	--	--	--	--	1
	Sulfate	200	--	--	--	--	1
	Total dissolved solids	492	--	--	--	--	1

4 Appendix E4

Appendix E4. Summary statistics for environmental water samples, Medicine Bow Mountains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Chugwater confining unit	Specific conductance ($\mu\text{S}/\text{cm}$)	448	--	--	--	--	1
	Hardness (as CaCO_3)	230	--	--	--	--	1
	Calcium	59.0	--	--	--	--	1
	Magnesium	20.0	--	--	--	--	1
	Sodium	7.1	--	--	--	--	1
	Potassium	1.3	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	0.20	--	--	--	--	1
	Alkalinity (as CaCO_3)	154	--	--	--	--	1
	Chloride	1.5	--	--	--	--	1
	Fluoride	1.1	--	--	--	--	1
	Silica	14.0	--	--	--	--	1
	Sulfate	82.0	--	--	--	--	1
	Total dissolved solids	314	--	--	--	--	1
	Nitrate (as N)	0.023	--	--	--	--	1
Boron	30.0	--	--	--	--	1	
Casper aquifer (Casper Formation)	pH (standard units)	7.6	--	--	--	8.1	2
	Specific conductance ($\mu\text{S}/\text{cm}$)	350	--	--	--	361	2
	Hardness (as CaCO_3)	178	--	--	--	191	2
	Calcium	61.0	--	--	--	65.0	2
	Magnesium	6.2	--	--	--	7.0	2
	Sodium	3.0	--	--	--	4.5	2
	Potassium	1.8	--	--	--	3.0	2
	Alkalinity (as CaCO_3)	166	--	--	--	175	2
	Chloride	2.1	--	--	--	3.0	2
	Fluoride	0.47	--	--	--	0.59	2
	Silica	4.4	--	--	--	10.0	2
	Sulfate	15.1	--	--	--	19.0	2
	Total dissolved solids	191	--	--	--	256	2
	Nitrate (as N)	0.29	--	--	--	0.44	2
	Arsenic	5.2	--	--	--	7.0	2
	Barium	<100	--	--	--	<100	2
	Boron	<100	--	--	--	290	2
	Cadmium	<10.0	--	--	--	<10.0	2
	Chromium	<50.0	--	--	--	<50.0	2
	Copper	<10.0	--	--	--	<10.0	2
	Iron	<50.0	--	--	--	<50.0	2
	Lead	<5.0	--	--	--	<50.0	2
	Manganese, unfiltered	<10.0	--	--	--	10.0	2
Mercury	<0.40	--	--	--	<1.0	2	
Selenium	<1.0	--	--	--	1.5	2	
Zinc	<10.0	--	--	--	170	2	

Appendix E4. Summary statistics for environmental water samples, Medicine Bow Mountains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Casper aquifer (Casper Formation)—Continued	Gross alpha radioactivity (picocuries per liter)	<1.0	--	--	--	3.5	2
	Gross beta radioactivity (picocuries per liter)	2.7	--	--	--	3.9	2
	Radium-226 (picocuries per liter)	<0.20	--	--	--	0.40	2
	Radium-228 (picocuries per liter)	<1.0	--	--	--	1.4	2
	Uranium	6.7	--	--	--	--	1
Casper aquifer (Fountain Formation)	pH (standard units)	8.1	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	402	--	--	--	--	1
	Calcium	75.0	--	--	--	--	1
	Magnesium	6.0	--	--	--	--	1
	Sodium	6.8	--	--	--	--	1
	Potassium	2.6	--	--	--	--	1
	Alkalinity (as CaCO_3)	250	--	--	--	--	1
	Chloride	1.1	--	--	--	--	1
	Sulfate	7.3	--	--	--	--	1
Total dissolved solids	236	--	--	--	--	1	
Precambrian basal confining unit	pH (standard units)	6.4	--	7.8	--	8.2	3
	Specific conductance ($\mu\text{S}/\text{cm}$)	77.0	140	155	166	180	5
	Hardness (as CaCO_3)	28.0	48.8	78.3	91.0	95.0	4
	Calcium	7.8	17.6	20.0	23.9	28.0	5
	Magnesium	2.1	2.5	3.8	3.8	6.1	5
	Sodium	3.5	3.7	3.9	5.1	6.8	5
	Potassium	0.80	0.90	1.0	1.0	2.0	5
	Sodium-adsorption ratio (unitless)	0.17	--	--	--	0.30	2
	Alkalinity (as CaCO_3)	33.6	64.2	75.5	81.0	91.8	5
	Chloride	0.40	0.70	0.90	1.0	1.9	5
	Fluoride	0.10	0.10	0.14	0.17	0.17	4
	Silica	12.0	14.0	18.1	23.2	26.2	4
	Sulfate	1.9	3.1	3.3	3.4	4.6	5
	Total dissolved solids	55.0	96.0	96.0	100	111	5
	Nitrate (as N)	--	0.034	0.073	0.13	0.15	4
	Nitrite (as N)	<0.010	--	--	--	<0.10	2
	Antimony	<1.0	--	--	--	<5.0	2
	Arsenic	<1.0	--	--	--	<1.0	2
	Barium	<100	--	--	--	<100	2
	Beryllium	<0.50	--	--	--	<10.0	2
	Cadmium	<0.50	--	--	--	<10.0	2
	Chromium	<50.0	--	--	--	<50.0	2
Copper	<1.0	--	--	--	<1.0	2	
Iron	<50.0	--	--	--	80.0	2	

6 Appendix E4

Appendix E4. Summary statistics for environmental water samples, Medicine Bow Mountains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Precambrian basal confining unit— Continued	Iron, unfiltered	30.0	--	--	--	600	2
	Lead	<1.0	--	--	--	<50.0	2
	Manganese	<10.0	--	--	--	<10.0	2
	Mercury	<0.20	--	--	--	<1.0	2
	Nickel	<20.0	--	--	--	<50.0	2
	Selenium	<1.0	--	--	--	7.0	2
	Zinc	<10.0	--	--	--	20.0	2
	Gross alpha radioactivity (picocuries per liter)	4.4	--	--	--	5.3	2
	Gross beta radioactivity (picocuries per liter)	<1.0	--	--	--	4.0	2
	Radium-226 (picocuries per liter)	<0.20	--	--	--	<0.20	2
	Radium-228 (picocuries per liter)	<1.0	--	--	--	2.0	2
	Uranium	<0.30	--	--	--	1.0	2

Appendix E5. Summary statistics for environmental water samples, Laramie Mountains, Wyoming.

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Quaternary alluvial aquifers	Dissolved oxygen	0.10	0.25	0.95	2.8	4.0	4
	pH (standard units)	6.5	7.1	7.2	7.3	7.7	5
	Specific conductance ($\mu\text{S}/\text{cm}$)	888	916	1,210	2,480	4,990	9
	Hardness (as CaCO_3)	370	385	410	450	480	4
	Calcium	82.0	90.5	110	129	136	4
	Magnesium	30.0	30.5	32.0	41.0	49.0	4
	Sodium	11.0	30.0	54.0	61.5	64.0	4
	Potassium	1.8	2.1	2.6	3.3	3.7	4
	Sodium-adsorption ratio (unitless)	0.22	0.63	1.2	1.4	1.4	4
	Alkalinity (as CaCO_3)	155	198	260	330	380	4
	Chloride	4.0	8.0	12.0	16.5	21.0	4
	Fluoride	0.60	0.70	0.85	1.2	1.5	4
	Silica	13.0	14.0	17.5	25.0	30.0	4
	Sulfate	86.0	143	236	306	340	4
	Total dissolved solids	578	614	664	666	928	5
	Nitrate+nitrite (as N)	--	0.36	3.6	8.2	9.9	4
	Nitrate (as N)	--	0.036	0.17	0.81	6.6	8
	Boron	--	80.0	105	155	190	4
	Iron, unfiltered	--	26.8	50.0	70.0	80.0	4
	Cody confining unit	Dissolved oxygen	0.40	--	--	--	--
pH (standard units)		7.4	--	--	--	--	1
Specific conductance ($\mu\text{S}/\text{cm}$)		7,200	--	--	--	--	1
Hardness (as CaCO_3)		2,960	--	--	--	--	1
Calcium		410	--	--	--	--	1
Magnesium		470	--	--	--	--	1
Sodium		1,100	--	--	--	--	1
Potassium		12.0	--	--	--	--	1
Sodium-adsorption ratio (unitless)		8.8	--	--	--	--	1
Alkalinity (as CaCO_3)		747	--	--	--	--	1
Chloride		130	--	--	--	--	1
Sulfate		4,800	--	--	--	--	1
Total dissolved solids		7,760	--	--	--	--	1
Nitrate+nitrite (as N)		4.5	--	--	--	--	1
Arsenic		11.0	--	--	--	--	1
Boron		1,700	--	--	--	--	1
Cadmium		<1.0	--	--	--	--	1
Chromium		<1.0	--	--	--	--	1
Copper		<1.0	--	--	--	--	1
Lead		<1.0	--	--	--	--	1
Molybdenum		17.0	--	--	--	--	1
Selenium		51.0	--	--	--	--	1

2 Appendix E5

Appendix E5. Summary statistics for environmental water samples, Laramie Mountains, Wyoming.—Continued

[-, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Cody confining unit— Continued	Vanadium	2.0	--	--	--	--	1
	Zinc	20.0	--	--	--	--	1
	Tritium, unfiltered (picocuries per liter)	75.0	--	--	--	--	1
Frontier aquifer	Dissolved oxygen	3.0	--	--	--	--	1
	pH (standard units)	7.5	7.7	7.9	8.2	8.5	4
	Specific conductance ($\mu\text{S}/\text{cm}$)	972	4,100	5,220	11,500	14,000	5
	Hardness (as CaCO_3)	250	980	2,670	7,690	8,100	6
	Calcium	58.0	200	394	440	440	6
	Magnesium	25.0	110	408	1,600	1,700	6
	Sodium	118	210	1,090	2,120	8,500	6
	Potassium	2.4	7.7	27.0	37.0	37.0	5
	Sodium-adsorption ratio (unitless)	1.8	3.3	8.3	17.8	42.2	6
	Alkalinity (as CaCO_3)	164	178	316	745	832	6
	Bromide	1.6	--	--	--	--	1
	Chloride	24.0	54.0	88.5	121	770	6
	Fluoride	0.40	0.60	0.80	4.1	12.0	5
	Silica	6.3	10.7	18.0	21.5	22.0	4
	Sulfate	293	2,000	4,600	12,000	26,000	6
	Total dissolved solids	646	3,270	10,800	16,400	37,800	5
	Nitrate+nitrite (as N)	16.0	--	--	--	--	1
	Nitrate (as N)	--	0.72	0.81	3.3	5.3	5
	Orthophosphate (as P)	<0.010	--	--	--	<1.6	2
	Arsenic	2.0	--	--	--	--	1
	Barium	75.0	--	--	--	600	2
	Beryllium	<20.0	--	--	--	<20.0	2
	Boron	--	880	1,700	1,900	2,890	5
	Cobalt	<120	--	--	--	<120	2
	Iron	<120	--	--	--	<120	2
	Iron, unfiltered	--	30.0	60.0	310	310	3
	Lithium	160	--	--	--	410	2
	Manganese	<40.0	--	--	--	<40.0	2
	Nickel	<400	--	--	--	<400	2
	Selenium	--	55.5	168	1,230	2,200	4
Strontium	3,000	--	--	--	7,400	2	
Zinc	--	30.0	260	340	340	3	
Tritium, unfiltered (picocuries per liter)	43.0	--	--	--	150	2	
Mowry-Thermopolis confining unit (Mowry Shale)	Hardness (as CaCO_3)	750	--	--	--	--	1
	Calcium	204	--	--	--	--	1
	Magnesium	58.0	--	--	--	--	1
	Sodium	103	--	--	--	--	1

Appendix E5. Summary statistics for environmental water samples, Laramie Mountains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Mowry-Thermopolis confining unit (Mowry Shale)—Continued	Potassium	9.0	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	1.6	--	--	--	--	1
	Alkalinity (as CaCO_3)	174	--	--	--	--	1
	Chloride	56.0	--	--	--	--	1
	Fluoride	0.60	--	--	--	--	1
	Silica	14.0	--	--	--	--	1
	Sulfate	680	--	--	--	--	1
	Total dissolved solids	1,320	--	--	--	--	1
	Orthophosphate (as P)	0.026	--	--	--	--	1
	Boron	780	--	--	--	--	1
	Gross alpha radioactivity (picocuries per liter)	8.0	--	--	--	--	1
	Gross beta radioactivity (picocuries per liter)	17.0	--	--	--	--	1
Uranium	4.7	--	--	--	--	1	
Muddy Sandstone aquifer	pH (standard units)	6.8	--	--	--	--	1
	Calcium	18.9	--	--	--	--	1
	Magnesium	3.8	--	--	--	--	1
	Sodium	5.1	--	--	--	--	1
	Potassium	1.2	--	--	--	--	1
	Alkalinity (as CaCO_3)	75.0	--	--	--	--	1
	Chloride	1.1	--	--	--	--	1
	Fluoride	0.050	--	--	--	--	1
	Silica	6.8	--	--	--	--	1
	Sulfate	8.0	--	--	--	--	1
	Total dissolved solids	76.0	--	--	--	--	1
Cloverly aquifer	pH (standard units)	6.5	7.9	8.0	8.6	8.9	12
	Specific conductance ($\mu\text{S}/\text{cm}$)	445	500	1,180	1,510	2,970	11
	Hardness (as CaCO_3)	14.0	--	28.0	--	130	3
	Calcium	1.0	3.0	24.0	62.1	75.3	13
	Magnesium	0.10	0.70	16.4	18.0	31.4	13
	Sodium	5.8	15.7	50.0	331	680	13
	Potassium	1.0	1.0	1.9	3.3	6.9	13
	Sodium-adsorption ratio (unitless)	1.9	--	33.6	--	79.4	3
	Alkalinity (as CaCO_3)	109	237	271	478	539	12
	Chloride	0.60	4.9	8.0	13.7	64.0	13
	Fluoride	0.27	0.41	0.60	1.8	2.1	13
	Silica	1.2	5.1	6.3	12.4	16.3	13
	Sulfate	13.0	72.2	143	236	1,310	13
	Total dissolved solids	228	310	419	884	2,090	13
	Nitrate (as N)	--	0.023	0.27	0.32	0.32	3
Boron	--	100	330	480	480	3	

4 Appendix E5

Appendix E5. Summary statistics for environmental water samples, Laramie Mountains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
	Iron, unfiltered	--	26.8	50.0	220	400	7
Morrison aquifer and confining unit	pH (standard units)	7.9	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	1,530	--	--	--	--	1
	Hardness (as CaCO_3)	310	--	--	--	--	1
	Calcium	45.0	--	--	--	--	1
	Magnesium	49.0	--	--	--	--	1
	Sodium	224	--	--	--	--	1
	Potassium	3.8	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	5.5	--	--	--	--	1
	Alkalinity (as CaCO_3)	193	--	--	--	--	1
	Chloride	25.0	--	--	--	--	1
	Fluoride	1.2	--	--	--	--	1
	Silica	7.8	--	--	--	--	1
	Sulfate	555	--	--	--	--	1
	Total dissolved solids	1,030	--	--	--	--	1
	Nitrate (as N)	0.045	--	--	--	--	1
	Boron	310	--	--	--	--	1
	Iron, unfiltered	1,100	--	--	--	--	1
Sundance aquifer	pH (standard units)	7.8	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	345	--	--	--	905	2
	Hardness (as CaCO_3)	170	--	--	--	--	1
	Calcium	9.3	--	--	--	29.0	2
	Magnesium	2.8	--	--	--	24.0	2
	Sodium	8.0	--	--	--	195	2
	Potassium	1.3	--	--	--	2.2	2
	Sodium-adsorption ratio (unitless)	0.27	--	--	--	--	1
	Alkalinity (as CaCO_3)	148	--	--	--	204	2
	Chloride	2.2	--	--	--	5.5	2
	Fluoride	0.23	--	--	--	0.30	2
	Silica	4.2	--	--	--	9.1	2
	Sulfate	31.0	--	--	--	287	2
	Total dissolved solids	200	--	--	--	604	2
	Nitrate (as N)	1.7	--	--	--	--	1
	Boron	10.0	--	--	--	--	1
Chugwater confining unit	pH (standard units)	6.3	7.2	7.5	7.7	7.8	11
	Specific conductance ($\mu\text{S}/\text{cm}$)	713	1,240	1,790	2,240	2,950	17
	Hardness (as CaCO_3)	260	430	1,000	1,100	1,400	9
	Calcium	46.0	194	265	476	606	18
	Magnesium	29.0	69.8	92.5	106	155	18
	Sodium	4.4	15.0	25.0	63.0	148	18
	Potassium	1.1	2.0	3.1	4.0	9.9	14

Appendix E5. Summary statistics for environmental water samples, Laramie Mountains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size	
Chugwater confining unit—Continued	Sodium-adsorption ratio (unitless)	0.10	0.20	0.58	1.8	3.4	7	
	Alkalinity (as CaCO_3)	107	124	163	228	392	18	
	Chloride	3.2	5.2	12.0	30.0	88.7	18	
	Fluoride	0.10	0.31	0.50	0.80	2.6	14	
	Silica	5.9	16.0	19.4	23.0	34.4	14	
	Sulfate	220	620	939	1,420	1,890	18	
	Total dissolved solids	456	1,030	1,550	2,090	2,890	18	
	Ammonia (as N)	<0.010	--	--	--	--	--	1
	Ammonia+organic nitrogen, unfiltered (as N)	0.16	--	--	--	--	--	1
	Ammonia, unfiltered (as N)	<0.010	--	--	--	--	--	1
	Nitrate+nitrite (as N)	3.0	--	--	--	--	--	1
	Nitrate+nitrite, unfiltered (as N)	1.5	--	--	--	--	--	1
	Nitrate (as N)	--	0.24	0.61	1.6	2.5	--	8
	Nitrite (as N)	<0.010	--	--	--	--	--	1
	Organic nitrogen, unfiltered (as N)	0.16	--	--	--	--	--	1
	Total nitrogen, unfiltered (as N)	1.7	--	--	--	--	--	1
	Orthophosphate (as P)	<0.010	--	--	--	--	--	1
	Phosphorus, unfiltered (as P)	0.010	--	--	--	--	--	1
	Aluminum	40.0	--	--	--	--	--	1
	Antimony	<1.0	--	--	--	--	--	1
	Arsenic	2.0	--	--	--	--	--	1
	Beryllium	<10.0	--	--	--	--	--	1
	Boron	--	85.0	120	220	350	--	8
	Chromium	<20.0	--	--	--	--	--	1
	Copper	2.0	--	--	--	--	--	1
	Iron	20.0	--	--	--	--	--	1
	Lead	2.0	--	--	--	--	--	1
	Lithium	20.0	--	--	--	--	--	1
	Manganese	<10.0	--	--	--	--	--	1
	Manganese, unfiltered	<10.0	--	--	--	--	--	1
	Mercury	<0.50	--	--	--	--	--	1
Molybdenum	4.0	--	--	--	--	--	1	
Selenium	4.0	--	--	--	--	--	1	
Vanadium	8.0	--	--	--	--	--	1	
Zinc	220	--	--	--	--	--	1	
Radon-222, unfiltered (picocuries per liter)	2,490	--	--	--	--	--	1	
Chugwater confining unit (Alcova Limestone)	pH (standard units)	7.8	--	--	--	8.0	2	
	Specific conductance ($\mu\text{S}/\text{cm}$)	944	--	--	--	963	2	
	Calcium	68.0	--	--	--	71.0	2	
	Magnesium	60.1	--	--	--	61.0	2	

6 Appendix E5

Appendix E5. Summary statistics for environmental water samples, Laramie Mountains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Chugwater confining unit (Alcova Limestone) —Continued	Sodium	45.0	--	--	--	49.0	2
	Potassium	5.6	--	--	--	5.7	2
	Alkalinity (as CaCO_3)	244	--	--	--	264	2
	Chloride	2.6	--	--	--	4.1	2
	Fluoride	0.45	--	--	--	0.45	2
	Silica	16.0	--	--	--	16.7	2
	Sulfate	242	--	--	--	279	2
	Total dissolved solids	628	--	--	--	648	2
	Iron, unfiltered	<50.0	--	--	--	<50.0	2
Goose Egg confining unit	pH (standard units)	7.3	7.4	7.6	7.8	7.9	12
	Specific conductance ($\mu\text{S}/\text{cm}$)	1,300	2,530	2,770	3,070	3,400	12
	Calcium	237	486	521	566	620	12
	Magnesium	29.5	97.3	117	213	236	12
	Sodium	3.0	22.1	49.5	71.4	268	12
	Potassium	0.50	2.8	5.3	6.6	9.9	12
	Alkalinity (as CaCO_3)	110	151	174	203	218	12
	Chloride	0.60	4.1	16.3	19.6	51.3	12
	Fluoride	0.26	0.50	0.61	1.0	1.8	12
	Silica	3.6	4.9	6.2	14.1	18.8	12
	Sulfate	592	1,550	1,740	2,010	2,220	12
	Total dissolved solids	1,030	2,400	2,650	2,910	3,220	12
	Satanka confining unit	pH (standard units)	7.2	7.3	7.3	7.5	7.7
Specific conductance ($\mu\text{S}/\text{cm}$)		361	410	1,190	1,260	2,550	10
Hardness (as CaCO_3)		150	211	605	751	1,800	10
Calcium		34.0	55.3	177	190	555	11
Magnesium		15.0	19.0	49.0	71.0	100	11
Sodium		2.7	9.0	12.2	29.0	70.0	10
Potassium		0.89	1.5	1.8	2.1	2.1	6
Sodium-adsorption ratio (unitless)		0.080	0.10	0.16	0.49	1.3	6
Alkalinity (as CaCO_3)		148	174	201	207	233	11
Chloride		2.0	3.7	8.0	19.8	72.0	11
Fluoride		0.10	0.11	0.25	0.58	3.8	8
Silica		9.4	11.0	17.4	20.0	29.7	7
Sulfate		4.0	12.0	474	542	1,590	11
Total dissolved solids		194	228	906	959	2,370	11
Nitrate+nitrite (as N)		--	1.2	2.2	2.2	2.2	3
Nitrate (as N)		--	0.38	0.82	1.8	28.7	9
Boron		--	40.0	40.0	180	300	5
Iron, unfiltered		50.0	--	--	--	--	1
Radon-222, unfiltered (picocuries per liter)		--	230	770	1,230	1,230	3

Appendix E5. Summary statistics for environmental water samples, Laramie Mountains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Casper aquifer (Casper Formation)	pH (standard units)	6.7	7.4	7.7	7.9	8.8	73
	Specific conductance ($\mu\text{S}/\text{cm}$)	199	358	391	470	1,750	94
	Hardness (as CaCO_3)	12.7	170	200	244	1,000	33
	Calcium	13.0	45.0	52.0	62.0	298	95
	Magnesium	5.0	15.0	19.3	23.8	155	94
	Sodium	0.20	2.0	3.6	7.0	160	96
	Potassium	0.32	0.68	0.93	1.3	8.9	82
	Sodium-adsorption ratio (unitless)	0.040	0.12	0.20	0.70	2.1	18
	Alkalinity (as CaCO_3)	81.0	185	206	222	451	96
	Chloride	0.010	0.59	2.0	4.9	83.0	95
	Fluoride	0.050	0.18	0.23	0.40	1.7	57
	Silica	2.9	8.7	9.8	12.0	31.0	73
	Sulfate	2.0	7.0	13.2	38.1	929	96
	Total dissolved solids	102	197	214	266	1,520	90
	Ammonia+organic nitrogen, unfiltered (as N)	0.050	--	--	--	--	1
	Nitrate+nitrite (as N)	--	0.46	1.2	2.0	4.7	12
	Nitrate (as N)	--	0.27	0.69	1.7	5.9	26
	Total nitrogen, unfiltered (as N)	0.12	--	--	--	--	1
	Phosphorus, unfiltered (as P)	0.010	--	--	--	0.030	2
	Antimony	<1.0	--	--	--	<1.0	2
	Beryllium	<1.0	--	--	--	<1.0	2
	Boron	--	22.5	49.9	140	270	17
	Manganese	<1.0	--	--	--	<1.0	2
	Manganese, unfiltered	<100	--	--	--	--	1
	Nickel	<20.0	--	--	--	<20.0	2
	Zinc	48.0	--	--	--	127	2
	Gross alpha radioactivity (picocuries per liter)	3.1	--	--	--	--	1
Gross beta radioactivity (picocuries per liter)	--	8.5	8.7	9.7	9.7	3	
Radium-226 (picocuries per liter)	--	0.20	1.0	1.0	1.0	3	
Radon-222, unfiltered (picocuries per liter)	--	210	390	1,080	1,080	3	
Tritium, unfiltered (picocuries per liter)	16.6	--	--	--	20.5	2	
Uranium	1.8	--	--	--	2.0	2	
Casper aquifer (Fountain Formation)	pH (standard units)	7.7	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	403	--	--	--	--	1
	Hardness (as CaCO_3)	190	--	--	--	--	1
	Calcium	59.5	--	--	--	--	1
	Magnesium	10.2	--	--	--	--	1
	Sodium	7.9	--	--	--	--	1

8 Appendix E5

Appendix E5. Summary statistics for environmental water samples, Laramie Mountains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Casper aquifer (Fountain Formation)— Continued	Potassium	1.8	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	0.25	--	--	--	--	1
	Alkalinity (as CaCO_3)	191	--	--	--	--	1
	Chloride	4.5	--	--	--	--	1
	Fluoride	0.50	--	--	--	--	1
	Silica	10.7	--	--	--	--	1
	Sulfate	14.6	--	--	--	--	1
	Total dissolved solids	224	--	--	--	--	1
	Ammonia (as N)	<0.010	--	--	--	--	1
	Nitrate+nitrite (as N)	0.32	--	--	--	--	1
	Nitrate (as N)	<0.32	--	--	--	--	1
	Nitrite (as N)	<0.010	--	--	--	--	1
	Orthophosphate (as P)	<0.010	--	--	--	--	1
	Radon-222, unfiltered (picocuries per liter)	5,720	--	--	--	--	1
Madison aquifer	pH (standard units)	7.7	7.8	7.8	7.8	7.8	4
	Specific conductance ($\mu\text{S}/\text{cm}$)	280	325	394	426	434	4
	Hardness (as CaCO_3)	174	--	--	--	--	1
	Calcium	36.9	43.0	49.5	54.5	59.0	4
	Magnesium	9.1	10.6	16.8	23.0	24.5	4
	Sodium	1.0	1.0	3.3	5.8	6.0	4
	Potassium	0.30	0.65	1.4	1.9	2.0	4
	Sodium-adsorption ratio (unitless)	0.20	--	--	--	--	1
	Alkalinity (as CaCO_3)	139	162	195	218	229	4
	Chloride	0.60	0.88	1.2	1.4	1.4	4
	Fluoride	0.050	0.11	0.17	0.19	0.20	4
	Silica	6.8	7.9	9.2	18.2	27.0	4
	Sulfate	6.2	10.8	17.5	22.3	25.0	4
	Total dissolved solids	219	--	231	--	257	3
	Nitrate+nitrite (as N)	0.87	--	--	--	--	1
	Phosphorus, unfiltered (as P)	0.13	--	--	--	--	1
	Iron, unfiltered	<50.0	--	--	--	<50.0	2
	Tritium, unfiltered (picocuries per liter)	124	--	--	--	--	1
Fremont Canyon aquifer	pH (standard units)	7.7	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	387	--	--	--	--	1
	Calcium	62.0	--	--	--	--	1
	Magnesium	17.0	--	--	--	--	1
	Sodium	0.80	--	--	--	--	1
	Potassium	0.70	--	--	--	--	1
	Alkalinity (as CaCO_3)	269	--	--	--	--	1
	Chloride	6.9	--	--	--	--	1

Appendix E5. Summary statistics for environmental water samples, Laramie Mountains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Fremont Canyon aquifer—Continued	Fluoride	0.090	--	--	--	--	1
	Sulfate	1.0	--	--	--	--	1
	Iron, unfiltered	<10.0	--	--	--	--	1
Precambrian basal confining unit	pH (standard units)	6.2	6.7	7.0	7.6	7.8	13
	Specific conductance ($\mu\text{S}/\text{cm}$)	53.0	120	228	312	500	12
	Hardness (as CaCO_3)	20.0	22.6	105	164	168	7
	Calcium	6.3	14.8	27.0	38.0	89.0	15
	Magnesium	1.1	2.9	5.7	8.3	26.7	15
	Sodium	0.90	2.6	4.3	5.6	7.7	15
	Potassium	0.59	0.75	0.98	1.4	2.8	12
	Sodium-adsorption ratio (unitless)	0.18	0.22	0.27	0.30	0.30	4
	Alkalinity (as CaCO_3)	20.0	45.1	121	178	278	15
	Chloride	0.11	0.60	2.9	6.0	15.0	15
	Fluoride	0.10	0.15	0.30	0.45	0.71	8
	Silica	7.6	8.7	11.6	16.8	31.4	12
	Sulfate	1.0	4.0	6.0	11.0	20.0	15
	Total dissolved solids	45.0	63.0	159	179	282	15
	Ammonia (as N)	<0.010	--	--	--	--	1
	Nitrate+nitrite (as N)	1.3	--	--	--	--	1
	Nitrate (as N)	--	0.68	1.3	5.5	9.3	4
	Nitrite (as N)	<0.010	--	--	--	--	1
	Orthophosphate (as P)	0.020	--	--	--	--	1
	Boron	40.0	--	--	--	120	2
Radon-222, unfiltered (picocuries per liter)	8,190	--	--	--	--	1	

Appendix E6. Summary statistics for environmental water samples, central Wyoming basins (north), Wyoming.

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Quaternary alluvial aquifers	Dissolved oxygen	0.10	0.40	0.60	2.0	5.4	13
	pH (standard units)	6.8	7.3	7.5	7.7	8.5	34
	Specific conductance ($\mu\text{S}/\text{cm}$)	265	871	1,540	2,870	8,280	33
	Hardness (as CaCO_3)	130	150	530	840	4,100	17
	Calcium	36.0	41.0	139	228	469	17
	Magnesium	10.0	14.0	52.0	82.0	735	17
	Sodium	6.0	11.0	120	250	1,330	17
	Potassium	1.5	2.4	6.6	12.0	38.7	16
	Sodium-adsorption ratio (unitless)	0.20	0.40	2.4	3.7	13.0	17
	Alkalinity (as CaCO_3)	120	150	252	344	490	17
	Bromide	0.19	--	--	--	--	1
	Chloride	3.3	8.5	25.0	39.0	200	17
	Fluoride	0.10	0.30	0.65	1.1	4.3	12
	Silica	13.0	14.7	16.0	26.0	41.0	15
	Sulfate	7.4	31.0	480	950	5,320	17
	Total dissolved solids	165	200	1,110	1,690	8,950	17
	Ammonia (as N)	--	0.001	0.006	0.025	0.45	17
	Nitrate+nitrite (as N)	--	0.55	2.2	5.7	207	28
	Nitrate (as N)	--	0.087	0.47	2.5	9.8	18
	Nitrite (as N)	--	0.002	0.005	0.011	0.084	17
	Orthophosphate (as P)	--	0.008	0.013	0.020	0.11	17
	Phosphorus, unfiltered (as P)	--	0.013	0.020	0.030	0.060	7
	Aluminum	<1.6	--	--	--	--	1
	Antimony	<0.30	--	--	--	--	1
	Arsenic	--	0.65	0.94	2.0	3.0	5
	Barium	<10.0	--	--	--	196	2
	Beryllium	<0.06	--	--	--	--	1
	Boron	--	240	510	820	1,200	11
	Cadmium	--	0.14	0.26	1.0	1.0	5
	Chromium	--	0.80	1.0	2.0	3.0	5
	Cobalt	0.27	--	--	--	--	1
	Copper	--	5.0	18.0	53.0	57.7	5
	Iron	<8.0	--	--	--	--	1
Iron, unfiltered	70.0	--	--	--	--	1	
Lithium	21.3	--	--	--	--	1	
Manganese	0.50	--	--	--	--	1	
Mercury	--	0.10	0.10	0.30	0.30	3	
Molybdenum	--	2.0	2.0	4.0	27.0	5	
Nickel	3.8	--	--	--	5.0	2	
Selenium	--	4.5	20.5	63.0	120	6	
Strontium	462	--	--	--	--	1	
Vanadium	--	1.2	2.0	3.0	5.0	5	

2 Appendix E6

Appendix E6. Summary statistics for environmental water samples, central Wyoming basins (north), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Quaternary alluvial aquifers—Continued	Zinc	--	10.0	24.0	30.0	150	5
	Gross beta radioactivity (picocuries per liter)	160	--	--	--	--	1
	Radon-222, unfiltered (picocuries per liter)	3,810	--	--	--	--	1
	Uranium	--	38.1	74.5	161	230	4
Quaternary terrace-deposit aquifers	pH (standard units)	7.7	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	3,590	--	--	--	--	1
	Hardness (as CaCO_3)	1,400	--	--	--	--	1
	Calcium	223	--	--	--	--	1
	Magnesium	195	--	--	--	--	1
	Sodium	411	--	--	--	--	1
	Potassium	7.1	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	4.9	--	--	--	--	1
	Alkalinity (as CaCO_3)	319	--	--	--	--	1
	Chloride	295	--	--	--	--	1
	Fluoride	1.0	--	--	--	--	1
	Silica	15.0	--	--	--	--	1
	Sulfate	1,510	--	--	--	--	1
	Total dissolved solids	2,890	--	--	--	--	1
	Nitrate+nitrite (as N)	8.1	--	--	--	--	1
	Arsenic	<1.0	--	--	--	--	1
	Barium	<10.0	--	--	--	--	1
	Boron	740	--	--	--	5,700	2
	Cadmium	<1.0	--	--	--	--	1
	Chromium	<1.0	--	--	--	--	1
	Copper	5.0	--	--	--	--	1
	Lead	5.0	--	--	--	--	1
	Mercury	0.40	--	--	--	--	1
	Molybdenum	15.0	--	--	--	--	1
	Nickel	4.0	--	--	--	--	1
	Selenium	<1.0	--	--	--	--	1
	Vanadium	<1.0	--	--	--	--	1
Zinc	<10.0	--	--	--	--	1	
Gross beta radioactivity (picocuries per liter)	1.2	--	--	--	--	1	
Uranium	<0.40	--	--	--	--	1	
Aquifers in Quaternary dune sand (eolian) deposits	pH (standard units)	8.0	8.1	8.2	8.4	8.8	9
	Specific conductance ($\mu\text{S}/\text{cm}$)	788	1,530	2,030	2,670	3,930	9
	Hardness (as CaCO_3)	51.2	229	264	600	1,350	9
	Calcium	11.5	59.1	64.0	122	284	9

Appendix E6. Summary statistics for environmental water samples, central Wyoming basins (north), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Aquifers in Quaternary dune sand (eolian) deposits—Continued	Magnesium	5.4	19.9	26.6	48.7	155	9
	Sodium	158	252	356	382	633	9
	Potassium	3.5	4.5	6.4	8.2	11.6	9
	Alkalinity (as CaCO_3)	176	256	285	299	318	9
	Chloride	25.4	63.4	98.9	124	157	9
	Sulfate	158	338	525	907	1,710	9
	Total dissolved solids	466	1,020	1,340	2,000	3,260	9
	Nitrate+nitrite (as N)	--	8.3	13.4	21.1	21.7	9
	Arsenic	<1.0	--	--	--	--	1
	Barium	100	--	--	--	--	1
	Boron	580	--	--	--	--	1
	Cadmium	1.0	--	--	--	--	1
	Chromium	10.0	--	--	--	--	1
	Copper	10.0	--	--	--	--	1
	Iron, unfiltered	--	10.9	30.0	108	1,920	9
	Lead	<5.0	--	--	--	--	1
	Mercury	<0.10	--	--	--	--	1
	Molybdenum	6.0	--	--	--	--	1
	Nickel	2.0	--	--	--	--	1
	Selenium	<1.0	--	--	--	--	1
	Vanadium	<1.0	--	--	--	--	1
	Zinc	40.0	--	--	--	--	1
	Gross beta radioactivity (picocuries per liter)	32.0	--	--	--	--	1
Uranium	30.0	--	--	--	--	1	
White River aquifer and confining unit	pH (standard units)	6.0	6.8	7.4	7.5	9.5	17
	Specific conductance ($\mu\text{S}/\text{cm}$)	90.0	205	298	333	529	18
	Hardness (as CaCO_3)	40.0	60.0	100	140	190	18
	Calcium	9.6	18.0	31.5	44.0	61.0	18
	Magnesium	2.2	3.9	5.7	7.4	10.0	18
	Sodium	2.3	6.5	12.5	22.0	96.0	18
	Potassium	1.2	2.4	3.2	4.0	6.6	18
	Sodium-adsorption ratio (unitless)	0.10	0.30	0.55	0.90	6.6	18
	Alkalinity (as CaCO_3)	45.0	91.0	132	158	200	18
	Chloride	0.20	1.3	2.7	3.6	18.0	18
	Fluoride	0.10	0.10	0.30	0.30	0.60	18
	Silica	10.0	20.0	24.5	43.0	94.0	18
	Sulfate	2.1	6.0	10.5	20.0	92.0	18
	Total dissolved solids	69.0	131	191	228	400	18
	Nitrate+nitrite (as N)	1.3	--	--	--	--	1
	Nitrate (as N)	--	0.16	0.47	0.79	1.6	15

4 Appendix E6

Appendix E6. Summary statistics for environmental water samples, central Wyoming basins (north), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
White River aquifer and confining unit—Continued	Boron	70.0	--	--	--	--	1
	Iron, unfiltered	--	30.0	60.0	95.0	1,400	16
	Uranium	1.7	--	--	--	--	1
Wagon Bed aquifer and confining unit	pH (standard units)	6.9	--	6.9	--	7.6	3
	Specific conductance ($\mu\text{S}/\text{cm}$)	292	--	469	--	485	3
	Hardness (as CaCO_3)	110	--	180	--	200	3
	Calcium	26.0	--	55.0	--	59.0	3
	Magnesium	11.0	--	11.0	--	13.0	3
	Sodium	19.0	--	20.0	--	22.0	3
	Potassium	3.6	--	6.2	--	6.2	3
	Sodium-adsorption ratio (unitless)	0.60	--	0.70	--	0.80	3
	Alkalinity (as CaCO_3)	144	--	230	--	236	3
	Chloride	1.3	--	3.5	--	3.9	3
	Fluoride	0.50	--	0.50	--	0.50	3
	Silica	53.0	--	55.0	--	71.0	3
	Sulfate	3.2	--	7.2	--	9.8	3
	Total dissolved solids	213	--	310	--	310	3
Wind River aquifer	pH (standard units)	6.7	7.5	7.7	8.2	8.4	14
	Specific conductance ($\mu\text{S}/\text{cm}$)	134	403	553	939	1,710	14
	Hardness (as CaCO_3)	52.0	56.0	110	190	490	14
	Calcium	16.0	17.0	33.5	58.0	120	14
	Magnesium	2.9	3.9	6.2	12.0	46.0	14
	Sodium	1.4	47.0	67.0	120	270	14
	Potassium	1.6	2.8	4.5	6.4	8.4	14
	Sodium-adsorption ratio (unitless)	0.10	1.5	2.4	6.1	7.4	14
	Alkalinity (as CaCO_3)	57.0	102	133	172	230	14
	Chloride	2.0	3.1	8.9	19.0	32.0	14
	Fluoride	0.10	0.10	0.30	0.60	0.70	14
	Silica	9.5	12.0	13.5	17.0	23.0	14
	Sulfate	2.8	63.0	93.0	270	790	14
	Total dissolved solids	82.0	241	346	619	1,310	14
	Nitrate (as N)	--	0.020	0.16	0.25	0.56	13
	Orthophosphate (as P)	0.007	--	--	--	0.091	2
	Aluminum	220	--	--	--	--	1
	Boron	--	70.0	125	415	700	4
	Iron, unfiltered	--	55.0	130	270	460	12
Gross beta radioactivity (picocuries per liter)	9.0	--	--	--	--	1	
Uranium	--	0.30	0.60	8.3	8.3	3	
Lance aquifer	pH (standard units)	7.0	7.0	7.8	8.4	8.4	7
	Specific conductance ($\mu\text{S}/\text{cm}$)	544	--	550	--	1,710	3
	Hardness (as CaCO_3)	38.0	135	220	270	830	8

Appendix E6. Summary statistics for environmental water samples, central Wyoming basins (north), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Lance aquifer— Continued	Calcium	10.7	43.5	55.0	75.0	174	8
	Magnesium	2.8	8.5	16.5	24.5	97.0	8
	Sodium	36.0	77.5	87.5	113	345	8
	Potassium	2.8	--	5.0	--	9.2	3
	Sodium-adsorption ratio (unitless)	1.0	1.2	2.7	3.0	9.4	6
	Alkalinity (as CaCO_3)	98.0	170	185	240	459	8
	Chloride	8.0	10.5	12.0	18.5	37.0	8
	Fluoride	0.45	--	0.48	--	0.70	3
	Silica	7.7	11.6	15.0	21.0	21.0	7
	Sulfate	69.0	94.0	145	286	712	7
	Total dissolved solids	350	380	557	624	1,270	7
	Nitrate+nitrite (as N)	<0.050	--	--	--	--	1
	Nitrate (as N)	<0.050	--	--	--	0.090	2
	Boron	40.0	--	--	--	--	1
	Iron, unfiltered	535	--	--	--	670	2
	Manganese, unfiltered	57.0	--	--	--	110	2
	Gross beta radioactivity (picocuries per liter)	3.0	--	--	--	--	1
	Radium-226 (picocuries per liter)	0.20	--	--	--	--	1
	Radium-228 (picocuries per liter)	2.9	--	--	--	--	1
	Uranium	<1.0	--	--	--	<1.0	2
Fox Hills aquifer	pH (standard units)	7.2	7.2	8.2	8.4	8.5	6
	Specific conductance ($\mu\text{S}/\text{cm}$)	2,190	--	2,200	--	2,550	3
	Hardness (as CaCO_3)	49.0	56.0	73.3	240	380	6
	Calcium	9.0	15.0	23.5	53.0	88.0	6
	Magnesium	3.0	3.0	6.0	27.0	40.0	6
	Sodium	168	298	457	580	650	6
	Potassium	2.0	--	2.0	--	2.0	3
	Sodium-adsorption ratio (unitless)	3.7	--	8.3	--	20.1	3
	Alkalinity (as CaCO_3)	133	180	245	320	361	6
	Chloride	16.0	18.0	52.5	70.0	100	6
	Sulfate	401	410	672	980	1,200	6
	Total dissolved solids	943	1,040	1,390	1,730	2,050	6
Mesaverde aquifer	pH (standard units)	7.2	--	--	--	8.5	2
	Specific conductance ($\mu\text{S}/\text{cm}$)	2,650	--	--	--	7,110	2
	Hardness (as CaCO_3)	10.0	--	--	--	--	1
	Calcium	1.0	--	--	--	--	1
	Magnesium	1.8	--	--	--	--	1
	Sodium	670	--	--	--	--	1
	Potassium	2.2	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	93.0	--	--	--	--	1
	Alkalinity (as CaCO_3)	872	--	--	--	--	1

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Appendix E6. Summary statistics for environmental water samples, central Wyoming basins (north), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Mesaverde aquifer— Continued	Chloride	52.0	--	--	--	--	1
	Fluoride	3.1	--	--	--	--	1
	Silica	22.0	--	--	--	--	1
	Sulfate	515	--	--	--	--	1
	Total dissolved solids	1,790	--	--	--	--	1
	Nitrate (as N)	0.023	--	--	--	--	1
	Boron	1,400	--	--	--	--	1
	Iron, unfiltered	80.0	--	--	--	--	1
	Radon-222, unfiltered (picocuries per liter)	1,140	--	--	--	--	1
	Cody confining unit	Dissolved oxygen	0.50	0.50	0.50	0.60	1.8
pH (standard units)		6.8	7.3	7.5	7.7	7.9	34
Specific conductance ($\mu\text{S}/\text{cm}$)		652	2,350	4,020	6,500	31,400	31
Hardness (as CaCO_3)		51.0	723	1,630	3,150	26,600	32
Calcium		14.0	165	295	480	1,100	32
Magnesium		3.8	84.5	165	420	6,200	32
Sodium		38.0	260	608	1,480	16,000	32
Potassium		3.2	5.7	9.8	22.0	120	31
Sodium-adsorption ratio (unitless)		0.98	4.1	7.0	10.8	77.0	32
Alkalinity (as CaCO_3)		17.0	269	377	502	797	32
Bromide		1.6	--	--	--	--	1
Chloride		9.5	47.0	89.5	160	950	32
Fluoride		0.30	0.45	0.65	2.2	23.0	12
Silica		8.1	13.0	16.5	18.0	24.0	12
Sulfate		140	1,050	2,120	3,300	68,000	32
Total dissolved solids		422	1,960	3,630	6,230	98,500	31
Nitrate+nitrite (as N)		--	3.2	15.0	56.0	1,600	21
Nitrate (as N)		1,300	--	--	--	--	1
Orthophosphate (as P)		<1.6	--	--	--	--	1
Barium		65.0	--	--	--	100	2
Beryllium		<20.0	--	--	--	--	1
Boron		--	420	660	1,100	1,900	23
Chromium		--	1.4	2.2	3.6	27.0	22
Cobalt		<120	--	--	--	--	1
Copper		--	5.0	10.2	20.8	180	22
Iron		<120	--	--	--	--	1
Iron, unfiltered		430	--	--	--	--	1
Lithium		4,600	--	--	--	--	1
Manganese		51.0	--	--	--	--	1
Mercury		<0.10	--	--	--	--	1
Molybdenum		--	2.8	6.1	13.3	48.0	22
Nickel		2.0	--	--	--	<400	2

Appendix E6. Summary statistics for environmental water samples, central Wyoming basins (north), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Cody confining unit— Continued	Selenium	--	18.0	340	1,400	20,000	33
	Strontium	13,000	--	--	--	--	1
	Vanadium	--	1.9	4.6	11.1	41.0	22
	Zinc	--	20.0	40.0	80.0	800	22
	Gross beta radioactivity (picocuries per liter)	1.7	--	--	--	--	1
	Tritium, unfiltered (picocuries per liter)	--	57.0	58.0	162	182	6
	Uranium	<0.40	--	--	--	--	1
Steele confining unit	pH (standard units)	8.4	--	8.4	--	8.5	3
	Specific conductance ($\mu\text{S}/\text{cm}$)	895	--	2,170	--	4,130	3
	Hardness (as CaCO_3)	40.0	--	500	--	1,100	3
	Calcium	12.0	--	90.0	--	180	3
	Magnesium	2.4	--	67.0	--	150	3
	Sodium	180	--	320	--	670	3
	Potassium	4.2	--	5.8	--	6.6	3
	Sodium-adsorption ratio (unitless)	6.2	--	8.9	--	12.0	3
	Alkalinity (as CaCO_3)	289	--	310	--	664	3
	Chloride	0.10	--	12.0	--	15.0	3
	Fluoride	0.10	--	0.20	--	0.80	3
	Silica	9.6	--	15.0	--	23.0	3
	Sulfate	110	--	840	--	1,700	3
	Total dissolved solids	511	--	1,530	--	3,160	3
	Nitrate (as N)	--	0.41	0.43	1.4	1.4	3
	Boron	--	30.0	200	950	950	3
	Iron, unfiltered	--	400	400	540	540	3
Frontier aquifer	pH (standard units)	7.9	8.0	8.2	8.5	9.6	9
	Specific conductance ($\mu\text{S}/\text{cm}$)	1,000	1,290	2,200	2,830	4,210	9
	Hardness (as CaCO_3)	3.0	11.0	271	508	1,800	9
	Calcium	0.40	3.2	69.4	141	275	9
	Magnesium	0.60	1.0	23.8	35.8	271	9
	Sodium	34.5	107	284	580	984	9
	Potassium	1.2	1.7	2.4	2.8	6.0	9
	Sodium-adsorption ratio (unitless)	77.0	--	110	--	180	3
	Alkalinity (as CaCO_3)	193	224	309	757	1,450	9
	Chloride	2.4	8.6	21.2	74.4	208	9
	Fluoride	1.9	--	7.3	--	12.0	3
	Silica	6.4	--	8.5	--	9.0	3
	Sulfate	64.0	317	425	646	1,900	9
	Total dissolved solids	708	978	1,470	1,780	3,570	9
	Ammonia+organic nitrogen, unfiltered (as N)	0.72	--	--	--	--	1

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Appendix E6. Summary statistics for environmental water samples, central Wyoming basins (north), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S/cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Frontier aquifer— Continued	Ammonia, unfiltered (as N)	0.64	--	--	--	--	1
	Nitrate+nitrite (as N)	--	0.019	0.81	10.7	17.1	6
	Nitrate+nitrite, unfiltered (as N)	0.020	--	--	--	--	1
	Nitrate (as N)	0.050	--	--	--	--	1
	Organic nitrogen, unfiltered (as N)	0.080	--	--	--	--	1
	Total nitrogen, unfiltered (as N)	0.74	--	--	--	--	1
	Phosphorus, unfiltered (as P)	0.030	--	--	--	--	1
	Aluminum	10.0	--	--	--	--	1
	Antimony	<1.0	--	--	--	--	1
	Arsenic	2.0	--	--	--	--	1
	Beryllium	<10.0	--	--	--	--	1
	Boron	--	1,400	1,900	3,100	3,100	3
	Copper	<2.0	--	--	--	--	1
	Iron	110	--	--	--	--	1
	Iron, unfiltered	--	62.0	252	461	2,650	8
	Lead	2.0	--	--	--	--	1
	Lithium	40.0	--	--	--	--	1
	Manganese	<10.0	--	--	--	--	1
	Manganese, unfiltered	<10.0	--	--	--	--	1
	Mercury	<0.50	--	--	--	--	1
Molybdenum	1.0	--	--	--	--	1	
Selenium	<1.0	--	--	--	20.0	2	
Zinc	20.0	--	--	--	--	1	
Cloverly Formation	pH (standard units)	8.0	8.2	8.5	8.8	8.9	5
	Specific conductance ($\mu\text{S/cm}$)	491	538	1,940	2,470	2,540	5
	Hardness (as CaCO_3)	2.0	--	--	--	30.0	2
	Calcium	1.0	1.0	1.0	1.0	9.8	5
	Magnesium	1.0	1.0	1.0	1.2	1.3	4
	Sodium	117	149	442	600	600	5
	Potassium	0.30	1.2	1.3	1.6	2.2	5
	Sodium-adsorption ratio (unitless)	41.0	--	--	--	48.0	2
	Alkalinity (as CaCO_3)	210	228	288	400	952	5
	Chloride	2.5	6.7	12.2	18.0	64.7	5
	Fluoride	0.70	0.70	2.4	2.8	9.4	5
	Silica	18.1	19.0	19.0	23.6	27.0	5
	Sulfate	34.2	74.0	330	546	958	5
	Total dissolved solids	322	402	1,290	1,570	1,770	5
	Ammonia (as N)	--	0.18	0.45	0.98	0.98	3
	Nitrate (as N)	0.050	--	--	--	--	1
	Nitrite (as N)	<0.10	--	--	--	<0.10	2
Boron	--	380	1,180	1,300	3,510	5	
Iron, unfiltered	50.0	--	--	--	120	2	

Appendix E6. Summary statistics for environmental water samples, central Wyoming basins (north), Wyoming.—Continued

[-, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Cloverly Formation— Continued	Manganese	--	20.0	20.0	120	120	3
	Vanadium	<100	--	--	--	<100	2
Casper aquifer	pH (standard units)	7.8	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	4,400	--	--	--	--	1
	Hardness (as CaCO_3)	1,800	--	--	--	--	1
	Calcium	510	--	--	--	--	1
	Magnesium	120	--	--	--	--	1
	Sodium	160	--	--	--	--	1
	Potassium	23.0	--	--	--	--	1
	Sodium-adsorption ratio (unitless)	1.7	--	--	--	--	1
	Alkalinity (as CaCO_3)	89.0	--	--	--	--	1
	Chloride	56.0	--	--	--	--	1
	Fluoride	3.0	--	--	--	--	1
	Silica	11.0	--	--	--	--	1
	Sulfate	2,000	--	--	--	--	1
	Total dissolved solids	2,930	--	--	--	--	1
	Ammonia+organic nitrogen, unfiltered (as N)	0.13	--	--	--	--	1
	Nitrate+nitrite (as N)	0.12	--	--	--	--	1
	Total nitrogen, unfiltered (as N)	0.25	--	--	--	--	1
	Phosphorus, unfiltered (as P)	0.010	--	--	--	--	1
Selenium	<1.0	--	--	--	--	1	
Madison aquifer	pH (standard units)	7.3	7.4	7.4	7.5	7.6	4
	Specific conductance ($\mu\text{S}/\text{cm}$)	3,660	--	4,140	--	4,600	3
	Hardness (as CaCO_3)	380	1,100	1,250	1,300	1,400	6
	Calcium	110	335	375	460	500	6
	Magnesium	25.0	36.0	46.0	64.0	82.0	6
	Sodium	77.0	452	513	734	1,310	6
	Potassium	9.8	37.0	51.0	58.0	82.0	5
	Sodium-adsorption ratio (unitless)	1.7	6.0	6.4	8.9	15.2	6
	Alkalinity (as CaCO_3)	78.0	92.0	102	130	180	6
	Bromide	0.40	--	--	--	--	1
	Chloride	70.0	322	528	623	1,180	6
	Fluoride	1.4	2.7	4.2	4.7	5.0	4
	Silica	19.0	24.5	33.5	38.5	40.0	4
	Sulfate	340	1,160	1,470	1,560	3,230	6
	Total dissolved solids	732	2,920	3,150	3,730	5,680	6
	Ammonia+organic nitrogen, unfiltered (as N)	<0.10	--	--	--	--	1
	Nitrate+nitrite (as N)	5.0	--	--	--	--	1
	Phosphorus (as P)	<0.010	--	--	--	--	1
	Aluminum	10.0	--	--	--	--	1

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Appendix E6. Summary statistics for environmental water samples, central Wyoming basins (north), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Madison aquifer— Continued	Arsenic	25.0	--	--	--	--	1
	Barium	<100	--	--	--	--	1
	Boron	--	455	710	955	1,200	4
	Iron	2,400	--	--	--	--	1
	Lithium	150	--	--	--	--	1
	Manganese	300	--	--	--	--	1
	Mercury	<0.50	--	--	--	--	1
	Molybdenum	27.0	--	--	--	--	1
	Selenium	<1.0	--	--	--	--	1
	Strontium	1,600	--	--	--	--	1
	Zinc	30.0	--	--	--	--	1
	Gross beta radioactivity (picocuries per liter)	350	--	--	--	--	1

Appendix E7. Summary statistics for environmental water samples, Great Plains, Wyoming.

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Quaternary alluvial aquifers	Dissolved oxygen	0.20	1.3	3.5	4.9	7.5	13
	pH (standard units)	6.6	7.2	7.4	7.6	8.6	127
	Specific conductance ($\mu\text{S}/\text{cm}$)	295	710	935	1,080	4,920	127
	Hardness (as CaCO_3)	46.0	185	270	320	480	56
	Calcium	16.0	56.0	77.0	98.0	140	57
	Magnesium	1.5	12.0	17.0	21.0	37.0	57
	Sodium	7.3	45.0	64.0	92.0	350	62
	Potassium	1.9	6.3	8.9	12.0	26.0	55
	Sodium-adsorption ratio (unitless)	0.23	1.2	1.6	2.6	11.0	54
	Alkalinity (as CaCO_3)	86.9	197	243	285	460	60
	Chloride	1.7	10.5	15.0	18.0	38.0	56
	Fluoride	0.20	0.40	0.64	0.80	1.6	58
	Silica	7.2	27.5	42.0	50.0	62.0	56
	Sulfate	10.0	63.0	159	210	700	58
	Total dissolved solids	207	442	528	658	1,530	55
	Ammonia (as N)	--	0.004	0.014	0.040	2.4	65
	Nitrate+nitrite (as N)	--	1.6	4.4	9.1	21.0	92
	Nitrate (as N)	--	0.27	0.74	2.0	17.2	96
	Nitrite (as N)	--	0.001	0.003	0.007	0.15	66
	Orthophosphate (as P)	--	0.020	0.030	0.050	0.18	65
	Phosphorus, unfiltered (as P)	--	0.013	0.018	0.025	0.060	9
	Antimony	<1.0	--	--	--	--	1
	Arsenic	5.0	--	--	--	<10.0	2
	Barium	80.0	--	--	--	<100	2
	Beryllium	<0.50	--	--	--	--	1
	Boron	--	90.0	115	220	880	46
	Cadmium	<0.50	--	--	--	<10.0	2
Chromium	<50.0	--	--	--	<50.0	2	
Copper	<10.0	--	--	--	--	1	
Iron	--	10.0	20.0	30.0	50.0	13	
Iron, unfiltered	--	10.0	20.0	60.0	5,600	33	
Lead	<1.0	--	--	--	<50.0	2	
Mercury	<0.50	--	--	--	<1.0	2	
Nickel	<20.0	--	--	--	--	1	
Radon-222, unfiltered (picocuries per liter)	--	495	535	760	980	4	
Quaternary terrace-deposit aquifers	Dissolved oxygen	0.20	2.7	5.1	5.9	6.3	8
	pH (standard units)	6.7	7.4	7.5	7.8	8.0	47
	Specific conductance ($\mu\text{S}/\text{cm}$)	335	610	808	1,060	1,970	47
	Hardness (as CaCO_3)	120	170	215	320	497	12
	Calcium	42.0	50.0	67.5	101	120	12
	Magnesium	4.4	9.0	12.0	17.0	48.0	12

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Appendix E7. Summary statistics for environmental water samples, Great Plains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Quaternary terrace-deposit aquifers—Continued	Sodium	10.0	10.0	20.0	42.5	57.0	12
	Potassium	0.70	2.8	4.7	11.5	16.0	8
	Sodium-adsorption ratio (unitless)	0.30	0.32	0.95	1.1	1.2	8
	Alkalinity (as CaCO_3)	134	147	163	223	280	12
	Chloride	5.0	10.5	12.5	17.0	26.0	12
	Fluoride	0.20	0.35	0.70	1.1	1.3	12
	Silica	21.0	35.5	43.0	49.0	55.0	12
	Sulfate	8.6	24.0	35.5	160	270	12
	Total dissolved solids	234	282	542	592	727	8
	Ammonia (as N)	--	0.003	0.007	0.014	0.050	35
	Ammonia+organic nitrogen, unfiltered (as N)	0.90	--	--	--	--	1
	Ammonia, unfiltered (as N)	0.040	--	--	--	--	1
	Nitrate+nitrite (as N)	--	3.7	6.9	12.5	24.8	38
	Nitrate+nitrite, unfiltered (as N)	11.0	--	--	--	--	1
	Nitrate (as N)	--	0.73	1.5	3.3	20.4	44
	Organic nitrogen, unfiltered (as N)	0.86	--	--	--	--	1
	Total nitrogen, unfiltered (as N)	12.0	--	--	--	--	1
	Orthophosphate (as P)	--	0.020	0.020	0.030	0.088	35
	Phosphorus, unfiltered (as P)	0.010	--	--	--	0.030	2
	Aluminum	30.0	--	--	--	--	1
	Arsenic	2.0	--	--	--	--	1
	Barium	240	--	--	--	--	1
	Boron	--	10.0	50.0	60.0	150	7
	Cadmium	<1.0	--	--	--	--	1
	Chromium	4.0	--	--	--	--	1
	Copper	1.0	--	--	--	--	1
	Iron	15.0	--	--	--	30.0	2
	Iron, unfiltered	--	20.0	20.0	20.0	30.0	5
	Lead	<1.0	--	--	--	--	1
	Manganese	<1.0	--	--	--	--	1
	Mercury	0.10	--	--	--	--	1
	Selenium	<1.0	--	--	--	<5.0	2
	Zinc	6.0	--	--	--	--	1
Gross beta radioactivity (picocuries per liter)	8.5	--	--	--	--	1	
Radium-226 (picocuries per liter)	0.14	--	--	--	--	1	
Radium-228 (picocuries per liter)	<1.0	--	--	--	--	1	
Radon-222, unfiltered (picocuries per liter)	--	270	510	570	570	3	
Uranium	5.8	--	--	--	--	1	

Appendix E7. Summary statistics for environmental water samples, Great Plains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Aquifers in Quaternary dune sand (eolian) deposits	Dissolved oxygen	4.9	--	--	--	--	1
	pH (standard units)	7.5	--	--	--	7.6	2
	Specific conductance ($\mu\text{S}/\text{cm}$)	763	--	--	--	1,060	2
	Ammonia (as N)	<0.040	--	--	--	--	1
	Nitrate+nitrite (as N)	9.1	--	--	--	--	1
	Nitrate (as N)	<9.1	--	--	--	--	1
	Nitrite (as N)	<0.006	--	--	--	--	1
	Orthophosphate (as P)	<0.020	--	--	--	--	1
Ogallala aquifer	Dissolved oxygen	0.10	1.1	2.6	6.9	8.6	8
	pH (standard units)	6.4	7.3	7.5	7.8	8.4	104
	Specific conductance ($\mu\text{S}/\text{cm}$)	128	311	452	760	1,940	105
	Hardness (as CaCO_3)	47.0	130	150	229	843	73
	Calcium	17.0	43.0	48.0	71.0	270	74
	Magnesium	1.1	5.7	7.8	13.0	41.0	75
	Sodium	3.2	6.3	9.7	17.0	160	73
	Potassium	1.6	2.1	3.2	4.1	7.4	54
	Sodium-adsorption ratio (unitless)	0.19	0.29	0.35	0.70	3.1	46
	Alkalinity (as CaCO_3)	48.0	130	141	176	368	74
	Bromide	0.040	0.040	0.13	0.27	0.31	4
	Chloride	1.0	3.1	5.6	25.0	190	74
	Fluoride	0.10	0.40	0.50	0.70	0.90	72
	Silica	2.5	22.5	26.0	35.1	65.0	61
	Sulfate	1.0	8.9	15.5	34.0	390	74
	Total dissolved solids	70.0	181	227	362	1,270	59
	Ammonia (as N)	--	0.006	0.015	0.054	0.33	15
	Ammonia+organic nitrogen, unfiltered (as N)	0.60	--	--	--	--	1
	Ammonia, unfiltered (as N)	0.070	--	--	--	--	1
	Nitrate+nitrite (as N)	--	2.2	3.6	7.4	22.0	45
	Nitrate+nitrite, unfiltered (as N)	2.6	--	--	--	--	1
	Nitrate (as N)	--	0.46	1.1	2.5	9.0	50
	Organic nitrogen, unfiltered (as N)	0.53	--	--	--	--	1
	Total nitrogen, unfiltered (as N)	3.2	--	--	--	--	1
	Nitrite (as N)	--	0.001	0.002	0.004	0.019	22
	Orthophosphate (as P)	--	0.016	0.022	0.040	1.6	15
	Phosphorus (as P)	--	0.022	0.032	0.066	0.066	3
	Phosphorus, unfiltered (as P)	--	0.030	0.050	0.050	0.070	7
	Dissolved organic carbon	--	0.50	1.1	3.4	3.4	3
	Arsenic	--	1.1	1.6	2.1	4.0	32
	Barium	--	74.2	109	160	260	32
	Boron	--	20.6	28.8	40.4	110	25
	Copper	--	0.96	1.7	3.2	15.0	31

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Appendix E7. Summary statistics for environmental water samples, Great Plains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size	
Ogallala aquifer— Continued	Iron	--	1.1	4.9	20.9	970	33	
	Iron, unfiltered	--	30.0	60.0	350	5,800	19	
	Lead	--	0.11	0.50	2.2	40.0	33	
	Lithium	--	6.0	9.1	16.0	16.0	3	
	Manganese	--	0.85	2.4	7.0	77.0	31	
	Nickel	--	0.83	0.96	1.1	1.2	9	
	Selenium	--	1.2	2.2	4.0	15.0	37	
	Strontium	--	188	217	570	570	3	
	Zinc	--	4.4	11.0	26.0	250	31	
	Gross alpha radioactivity (picocuries per liter)	--	1.1	3.0	5.0	11.0	9	
	Gross beta radioactivity (picocuries per liter)	--	1.3	5.1	8.4	13.5	6	
	Radium-226 (picocuries per liter)	--	0.20	0.28	0.39	0.60	9	
	Radium-228 (picocuries per liter)	--	0.41	0.63	0.98	2.8	9	
	Radon-222, unfiltered (picocuries per liter)	--	414	532	630	930	20	
	Tritium, unfiltered (picocuries per liter)	25.0	--	--	--	81.9	2	
	Uranium	--	1.5	2.4	12.0	14.8	11	
	Arikaree aquifer	Dissolved oxygen	4.7	--	7.1	--	7.3	3
		pH (standard units)	7.0	7.6	7.8	8.2	8.7	35
Specific conductance ($\mu\text{S}/\text{cm}$)		285	340	450	746	2,110	37	
Hardness (as CaCO_3)		69.0	130	171	208	485	31	
Calcium		21.0	40.5	50.5	62.0	140	32	
Magnesium		0.90	7.1	9.4	12.5	40.0	32	
Sodium		4.3	9.8	16.0	34.0	118	32	
Potassium		1.9	3.5	4.4	5.6	16.0	25	
Sodium-adsorption ratio (unitless)		0.20	0.40	0.53	1.2	4.4	23	
Alkalinity (as CaCO_3)		107	141	171	201	320	32	
Chloride		2.0	5.1	6.3	12.0	30.0	32	
Fluoride		0.20	0.35	0.60	0.80	1.3	28	
Silica		18.0	40.0	50.0	55.0	67.0	30	
Sulfate		1.0	13.5	17.0	30.0	300	31	
Total dissolved solids		202	242	265	397	868	26	
Nitrate+nitrite (as N)		--	2.1	3.1	4.1	8.1	15	
Nitrate (as N)		--	1.0	2.1	4.4	8.1	23	
Phosphorus, unfiltered (as P)		--	0.040	0.050	0.060	0.080	9	
Antimony		<1.0	--	--	--	<1.0	2	
Barium		--	100	100	250	250	3	
Beryllium		<0.50	--	--	--	<0.50	2	
Boron	--	26.3	47.3	85.0	580	17		

Appendix E7. Summary statistics for environmental water samples, Great Plains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Arikaree aquifer— Continued	Iron	--	28.3	36.7	50.0	90.0	5
	Iron, unfiltered	--	30.0	90.0	165	260	8
	Molybdenum	<100	--	--	--	--	1
	Vanadium	<100	--	--	--	--	1
	Gross alpha radioactivity (picocuries per liter)	6.2	--	--	--	7.1	2
	Gross beta radioactivity (picocuries per liter)	6.9	--	--	--	7.5	2
	Radium-228 (picocuries per liter)	<1.0	--	--	--	<1.0	2
	Radon-222, unfiltered (picocuries per liter)	--	260	520	1,620	7,000	7
	Uranium	--	2.8	6.7	7.0	7.0	3
White River aquifer/ confining unit	Dissolved oxygen	3.8	--	--	--	--	1
	pH (standard units)	7.1	7.5	7.8	8.1	8.8	53
	Specific conductance ($\mu\text{S}/\text{cm}$)	269	422	529	1,030	5,450	54
	Hardness (as CaCO_3)	0.73	93.0	147	210	960	38
	Calcium	0.11	31.4	53.0	75.1	305	51
	Magnesium	0.11	5.0	8.5	13.0	57.0	51
	Sodium	4.1	17.2	32.0	91.6	1,130	50
	Potassium	2.6	4.4	7.1	14.3	46.0	39
	Sodium-adsorption ratio (unitless)	0.15	1.3	4.6	17.5	309	24
	Alkalinity (as CaCO_3)	112	160	211	318	581	51
	Chloride	1.4	4.9	8.4	22.5	277	52
	Fluoride	0.10	0.40	0.60	0.80	3.2	48
	Silica	9.3	21.1	35.4	57.0	72.0	46
	Sulfate	6.7	19.7	28.0	90.5	2,750	52
	Total dissolved solids	182	245	337	701	4,540	43
	Ammonia (as N)	<0.020	--	--	--	--	1
	Nitrate+nitrite (as N)	--	0.75	1.2	1.9	3.8	9
	Nitrate (as N)	--	0.18	0.71	2.8	22.0	28
	Orthophosphate (as P)	0.036	--	--	--	--	1
	Phosphorus, unfiltered (as P)	--	0.010	0.030	0.10	0.10	3
	Boron	--	54.4	131	660	11,000	25
	Iron, unfiltered	--	20.0	50.0	240	6,900	18
	Gross alpha radioactivity (picocuries per liter)	--	6.3	8.6	10.7	13.1	6
	Gross beta radioactivity (picocuries per liter)	--	4.3	7.7	12.2	15.7	4
Radium-226 (picocuries per liter)	--	0.10	0.14	0.21	0.60	10	
Radon-222, unfiltered (picocuries per liter)	--	420	500	1,140	2,880	7	
Uranium	--	10.0	38.0	120	200	9	

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Appendix E7. Summary statistics for environmental water samples, Great Plains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Brule aquifer/confining unit	pH (standard units)	7.0	7.6	7.8	8.0	8.5	51
	Specific conductance ($\mu\text{S}/\text{cm}$)	310	360	457	594	1,080	54
	Hardness (as CaCO_3)	31.0	120	140	190	312	51
	Calcium	2.7	32.0	39.0	55.0	91.0	53
	Magnesium	1.0	7.5	11.0	14.0	25.0	53
	Sodium	1.1	18.0	32.0	49.0	217	53
	Potassium	2.3	4.5	6.5	7.9	39.0	30
	Sodium-adsorption ratio (unitless)	0.44	0.60	1.5	1.8	11.0	25
	Alkalinity (as CaCO_3)	107	144	162	221	412	54
	Chloride	2.0	6.0	9.0	15.0	45.0	53
	Fluoride	0.20	0.60	0.70	0.80	1.5	50
	Silica	10.4	51.0	55.0	61.0	82.0	47
	Sulfate	9.1	19.0	32.0	44.0	88.0	54
	Total dissolved solids	214	267	357	468	676	32
	Nitrate+nitrite (as N)	--	4.6	5.8	19.0	27.0	7
	Nitrate (as N)	--	0.34	0.92	2.5	11.0	49
	Orthophosphate (as P)	--	0.030	0.030	0.18	0.18	3
	Arsenic	--	3.0	4.0	5.0	5.0	3
	Boron	--	40.0	100	210	16,000	34
	Iron	--	9.6	14.7	22.5	50.0	10
	Iron, unfiltered	--	9.0	21.3	50.0	290	20
	Manganese, unfiltered	<10.0	--	--	--	<10.0	2
	Zinc	--	10.0	20.0	30.0	30.0	3
	Gross alpha radioactivity (picocuries per liter)	2.8	--	--	--	10.3	2
	Radium-226 (picocuries per liter)	--	0.18	0.20	0.30	0.50	5
	Radium-228 (picocuries per liter)	<1.0	--	--	--	--	1
Radon-222, unfiltered (picocuries per liter)	662	--	--	--	731	2	
Uranium	--	16.0	17.0	20.0	20.0	5	
Chadron aquifer/confining unit	pH (standard units)	6.5	7.8	8.3	8.6	8.9	10
	Specific conductance ($\mu\text{S}/\text{cm}$)	358	755	822	1,160	1,460	10
	Hardness (as CaCO_3)	7.0	10.0	39.5	110	210	8
	Calcium	1.8	2.1	4.0	24.0	54.0	11
	Magnesium	0.30	0.90	2.2	4.9	18.0	11
	Sodium	25.9	40.0	198	262	341	11
	Potassium	3.3	3.8	4.0	7.1	11.0	11
	Sodium-adsorption ratio (unitless)	1.2	1.6	25.0	28.0	33.0	7
	Alkalinity (as CaCO_3)	112	169	398	422	604	11
	Chloride	4.5	7.4	10.5	68.0	99.0	11
	Fluoride	0.50	0.60	1.4	1.6	1.9	11

Appendix E7. Summary statistics for environmental water samples, Great Plains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Chadron aquifer/ confining unit— continued	Silica	8.5	8.8	11.0	22.0	50.0	11
	Sulfate	7.7	11.2	29.0	102	298	11
	Total dissolved solids	202	350	512	713	996	11
	Nitrate+nitrite (as N)	--	0.20	0.34	1.1	1.1	3
	Nitrate (as N)	--	0.16	0.25	1.0	3.2	5
	Nitrite (as N)	<0.10	--	--	--	--	1
	Beryllium	<0.50	--	--	--	--	1
	Boron	--	120	365	420	540	10
	Iron, unfiltered	--	12.6	53.3	610	1,920	7
	Zinc	--	18.0	30.0	590	1,150	4
	Gross alpha radioactivity (picocuries per liter)	8.7	--	--	--	--	1
	Gross beta radioactivity (picocuries per liter)	13.8	--	--	--	--	1
	Radium-228 (picocuries per liter)	<1.0	--	--	--	--	1
	Radon-222, unfiltered (picocuries per liter)	405	--	--	--	--	1
	Wasatch aquifer	pH (standard units)	5.8	7.3	7.7	7.9	8.5
Specific conductance ($\mu\text{S}/\text{cm}$)		550	620	910	1,450	3,670	10
Hardness (as CaCO_3)		44.0	203	430	807	2,330	9
Calcium		9.2	46.0	120	220	570	9
Magnesium		5.1	18.0	31.0	62.0	220	9
Sodium		9.6	20.0	42.0	49.0	130	9
Potassium		1.1	4.7	7.4	13.0	18.0	9
Sodium-adsorption ratio (unitless)		0.30	0.38	0.54	0.65	8.5	9
Alkalinity (as CaCO_3)		130	230	270	489	531	9
Chloride		4.0	5.4	8.9	24.0	31.0	9
Fluoride		0.10	0.20	0.30	0.40	1.5	9
Silica		7.6	8.6	11.0	17.0	27.0	9
Sulfate		3.0	42.0	100	140	2,100	9
Total dissolved solids		228	376	516	911	3,200	9
Ammonia (as N)		--	0.83	1.2	1.6	1.6	3
Nitrate+nitrite (as N)		--	0.002	0.020	0.90	17.0	9
Boron		--	115	120	660	1,200	4
Iron		--	100	630	2,000	15,000	6
Lead		--	10.0	100	100	100	3
Manganese		--	5.0	270	380	1,000	6
Strontium		--	1,800	2,600	3,600	3,900	4
Zinc		--	40.0	60.0	72.0	72.0	3
Gross alpha radioactivity (picocuries per liter)		27.0	--	--	--	82.0	2
Gross beta radioactivity (picocuries per liter)		7.7	--	--	--	12.0	2

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Appendix E7. Summary statistics for environmental water samples, Great Plains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Wasatch aquifer— Continued	Radium-226 (picocuries per liter)	0.35	--	--	--	0.88	2
	Radon-222, unfiltered (picocuries per liter)	770	--	--	--	--	1
	Uranium	31.3	--	--	--	94.2	2
Fort Union aquifer	Dissolved oxygen	0.10	--	--	--	--	1
	pH (standard units)	7.0	7.7	8.0	8.2	8.7	5
	Specific conductance ($\mu\text{S}/\text{cm}$)	673	685	925	3,390	3,620	5
	Hardness (as CaCO_3)	3.0	36.5	250	865	1,300	4
	Calcium	0.70	8.4	79.0	248	353	4
	Magnesium	0.40	3.9	12.2	57.5	98.0	4
	Sodium	28.0	82.5	150	297	432	4
	Potassium	0.40	2.5	6.6	23.3	38.0	4
	Sodium-adsorption ratio (unitless)	0.60	2.9	6.2	22.6	38.0	4
	Alkalinity (as CaCO_3)	234	241	273	326	354	4
	Chloride	3.0	8.0	18.5	38.0	52.0	4
	Fluoride	0.30	0.30	0.30	0.70	1.1	4
	Silica	5.4	7.7	11.5	15.5	18.0	4
	Sulfate	43.0	73.5	141	1,000	1,830	4
	Total dissolved solids	417	421	567	1,870	3,030	4
	Ammonia (as N)	<0.040	--	--	--	--	1
	Nitrate+nitrite (as N)	10.0	--	--	--	--	1
	Nitrate (as N)	--	0.090	0.72	7.5	10.0	5
	Nitrite (as N)	0.006	--	--	--	--	1
	Orthophosphate (as P)	<0.020	--	--	--	--	1
	Boron	--	80.0	140	250	300	4
	Iron, unfiltered	--	45.0	55.0	880	1,700	4
Lance aquifer	pH (standard units)	7.0	7.7	8.3	8.6	9.8	19
	Specific conductance ($\mu\text{S}/\text{cm}$)	391	951	1,170	1,320	2,770	19
	Hardness (as CaCO_3)	6.0	12.0	20.0	50.0	170	11
	Calcium	1.7	3.5	6.2	14.0	50.0	15
	Magnesium	0.10	1.1	1.7	4.1	16.3	15
	Sodium	60.0	84.0	273	300	616	15
	Potassium	2.4	3.9	5.4	6.3	18.0	13
	Sodium-adsorption ratio (unitless)	2.0	26.0	29.0	38.5	42.0	8
	Alkalinity (as CaCO_3)	167	272	468	555	916	15
	Chloride	3.6	7.5	23.0	37.0	130	15
	Fluoride	0.30	0.60	1.0	2.2	3.4	14
	Silica	11.0	11.0	13.0	17.0	53.0	13
	Sulfate	0.90	30.0	41.0	160	405	15
	Total dissolved solids	264	592	699	820	1,950	13
	Ammonia (as N)	<0.010	--	--	--	0.13	2
Nitrate+nitrite (as N)	--	0.060	0.20	1.6	4.2	5	

Appendix E7. Summary statistics for environmental water samples, Great Plains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Lance aquifer— Continued	Nitrate (as N)	--	0.050	0.40	2.0	8.8	10
	Orthophosphate (as P)	0.020	--	--	--	0.18	2
	Antimony	<1.0	--	--	--	<5.0	2
	Beryllium	<1.0	--	--	--	<5.0	2
	Boron	--	180	210	770	1,230	11
	Iron	--	40.0	50.0	190	1,220	5
	Iron, unfiltered	--	40.4	75.3	410	970	8
	Selenium	--	1.5	3.3	6.0	50.0	5
	Zinc	--	23.7	40.0	595	1,150	4
	Gross alpha radioactivity (picocuries per liter)	8.5	--	--	--	--	1
	Gross beta radioactivity (picocuries per liter)	9.0	--	--	--	--	1
	Radium-226 (picocuries per liter)	--	0.13	0.20	0.70	0.90	7
	Radium-228 (picocuries per liter)	<1.0	--	--	--	--	1
	Uranium	--	15.0	62.0	151	270	7
	Fox Hills aquifer	Hardness (as CaCO_3)	180	--	--	--	--
Calcium		54.0	--	--	--	--	1
Magnesium		12.0	--	--	--	--	1
Sodium		9.4	--	--	--	--	1
Alkalinity (as CaCO_3)		179	--	--	--	--	1
Chloride		7.5	--	--	--	--	1
Silica		33.0	--	--	--	--	1
Sulfate		12.0	--	--	--	--	1
Nitrate (as N)		0.45	--	--	--	--	1
Pierre confining unit	pH (standard units)	9.2	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	637	--	--	--	--	1
	Hardness (as CaCO_3)	17.6	--	--	--	--	1
	Calcium	5.0	--	--	--	--	1
	Magnesium	1.0	--	--	--	--	1
	Sodium	140	--	--	--	--	1
	Potassium	3.0	--	--	--	--	1
	Alkalinity (as CaCO_3)	271	--	--	--	--	1
	Chloride	10.0	--	--	--	--	1
	Fluoride	1.0	--	--	--	--	1
	Silica	9.0	--	--	--	--	1
	Sulfate	25.0	--	--	--	--	1
	Total dissolved solids	379	--	--	--	--	1
	Nitrate+nitrite (as N)	<0.10	--	--	--	--	1
	Nitrite (as N)	<0.10	--	--	--	--	1
Iron, unfiltered	940	--	--	--	--	1	
Manganese, unfiltered	20.0	--	--	--	--	1	

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Appendix E7. Summary statistics for environmental water samples, Great Plains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Pierre confining unit— Continued	Gross alpha radioactivity (picocuries per liter)	<3.0	--	--	--	--	1
	Gross beta radioactivity (picocuries per liter)	3.5	--	--	--	--	1
	Radium-226 (picocuries per liter)	<0.20	--	--	--	--	1
	Radium-228 (picocuries per liter)	<1.0	--	--	--	--	1
	Uranium	0.30	--	--	--	--	1
Cloverly aquifer	pH (standard units)	7.5	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	652	--	--	--	--	1
	Calcium	51.6	--	--	--	--	1
	Magnesium	14.4	--	--	--	--	1
	Sodium	63.7	--	--	--	--	1
	Potassium	3.9	--	--	--	--	1
	Alkalinity (as CaCO_3)	233	--	--	--	--	1
	Chloride	5.7	--	--	--	--	1
	Fluoride	0.29	--	--	--	--	1
	Silica	3.8	--	--	--	--	1
	Sulfate	129	--	--	--	--	1
	Total dissolved solids	385	--	--	--	--	1
Sundance aquifer	pH (standard units)	8.4	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	475	--	--	--	--	1
	Calcium	11.3	--	--	--	--	1
	Magnesium	0.40	--	--	--	--	1
	Sodium	85.2	--	--	--	--	1
	Potassium	7.8	--	--	--	--	1
	Alkalinity (as CaCO_3)	223	--	--	--	--	1
	Chloride	4.3	--	--	--	--	1
	Fluoride	0.080	--	--	--	--	1
	Silica	13.2	--	--	--	--	1
	Sulfate	40.0	--	--	--	--	1
	Total dissolved solids	260	--	--	--	--	1
Chugwater confining unit	pH (standard units)	8.0	--	--	--	--	1
	Specific conductance ($\mu\text{S}/\text{cm}$)	865	--	--	--	--	1
	Calcium	5.6	--	--	--	--	1
	Magnesium	0.90	--	--	--	--	1
	Sodium	151	--	--	--	--	1
	Potassium	7.0	--	--	--	--	1
	Alkalinity (as CaCO_3)	283	--	--	--	--	1
	Chloride	24.1	--	--	--	--	1
	Fluoride	1.5	--	--	--	--	1
	Silica	15.4	--	--	--	--	1
	Sulfate	106	--	--	--	--	1
	Total dissolved solids	436	--	--	--	--	1

Appendix E7. Summary statistics for environmental water samples, Great Plains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Casper aquifer	pH (standard units)	7.0	7.4	7.9	8.0	8.1	10
	Specific conductance ($\mu\text{S}/\text{cm}$)	316	360	449	570	1,160	10
	Hardness (as CaCO_3)	110	162	220	244	300	5
	Calcium	37.0	42.9	51.3	63.3	153	10
	Magnesium	4.8	12.0	20.6	23.0	41.8	10
	Sodium	3.7	8.1	9.6	26.0	45.2	10
	Potassium	0.40	2.0	3.7	5.1	9.0	10
	Sodium-adsorption ratio (unitless)	0.34	--	0.75	--	0.80	3
	Alkalinity (as CaCO_3)	118	167	190	223	343	10
	Chloride	1.8	2.5	3.5	11.0	43.4	10
	Fluoride	0.20	0.20	0.44	0.54	0.75	8
	Silica	1.2	8.0	14.8	22.0	29.6	8
	Sulfate	10.0	15.8	26.0	83.0	386	10
	Total dissolved solids	172	207	259	322	765	10
	Nitrate+nitrite (as N)	--	0.49	0.66	0.80	0.80	3
	Nitrate (as N)	--	0.32	0.80	0.86	0.86	3
	Nitrite (as N)	0.020	--	--	--	<0.20	2
	Phosphorus, unfiltered (as P)	0.33	--	--	--	--	1
	Antimony	<1.0	--	--	--	--	1
	Arsenic	--	6.0	11.0	17.0	17.0	3
	Beryllium	<1.0	--	--	--	--	1
	Boron	--	100	120	290	290	3
	Iron, unfiltered	340	--	--	--	--	1
	Manganese	<20.0	--	--	--	<20.0	2
	Nickel	<50.0	--	--	--	--	1
	Zinc	150	--	--	--	300	2
Gross beta radioactivity (picocuries per liter)	3.8	--	--	--	4.0	2	
Radium-226 (picocuries per liter)	<0.20	--	--	--	--	1	
Radium-228 (picocuries per liter)	<1.0	--	--	--	<1.0	2	
Hartville aquifer	pH (standard units)	7.6	7.9	8.0	8.1	8.1	9
	Specific conductance ($\mu\text{S}/\text{cm}$)	341	406	472	484	780	10
	Hardness (as CaCO_3)	162	--	166	--	216	3
	Calcium	23.0	33.0	40.3	45.8	91.0	10
	Magnesium	6.0	8.8	13.5	17.0	25.0	10
	Sodium	17.9	29.5	48.0	54.0	75.7	10
	Potassium	4.6	8.0	12.0	13.0	13.8	10
	Alkalinity (as CaCO_3)	174	187	196	213	242	10
	Chloride	1.0	2.0	4.5	6.0	29.0	10
	Fluoride	0.40	0.70	1.3	1.6	1.7	9
	Silica	4.5	5.2	9.2	16.9	57.5	9
	Sulfate	13.0	21.0	50.0	64.0	185	10

Appendix E7. Summary statistics for environmental water samples, Great Plains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Hartville aquifer— Continued	Total dissolved solids	196	240	286	316	472	10
	Nitrate+nitrite (as N)	--	0.30	1.2	1.2	1.4	5
	Aluminum	<100	--	--	--	<100	2
	Boron	<100	--	--	--	100	2
	Iron	--	17.4	80.0	160	3,960	6
	Iron, unfiltered	--	190	240	1,050	1,050	3
	Manganese, unfiltered	<10.0	--	--	--	20.0	2
	Zinc	<10.0	--	--	--	60.0	2
	Gross beta radioactivity (picocuries per liter)	8.5	--	--	--	9.6	2
	Radon-222, unfiltered (picocuries per liter)	201	--	--	--	--	1
	Uranium	--	9.1	11.0	11.0	11.0	3
Madison aquifer	pH (standard units)	7.1	--	--	--	7.2	2
	Specific conductance ($\mu\text{S}/\text{cm}$)	1,610	--	--	--	1,620	2
	Hardness (as CaCO_3)	530	--	--	--	640	2
	Calcium	13.0	--	160	--	190	3
	Magnesium	4.0	--	32.0	--	39.0	3
	Sodium	140	--	140	--	260	3
	Potassium	20.0	--	21.0	--	24.0	3
	Sodium-adsorption ratio (unitless)	2.5	--	--	--	2.6	2
	Alkalinity (as CaCO_3)	120	--	126	--	195	3
	Chloride	42.0	--	100	--	130	3
	Fluoride	1.6	--	--	--	2.3	2
	Silica	32.0	--	--	--	39.0	2
	Sulfate	390	--	590	--	620	3
	Total dissolved solids	843	--	1,160	--	1,250	3
	Nitrate+nitrite (as N)	0.090	--	--	--	--	1
	Aluminum	10.0	--	--	--	760	2
	Arsenic	5.0	--	--	--	--	1
	Barium	80.0	--	--	--	--	1
	Beryllium	<1.0	--	--	--	<5.0	2
	Boron	230	--	--	--	310	2
	Cadmium	<1.0	--	--	--	<9.0	2
	Chromium	10.0	--	--	--	<20.0	2
	Cobalt	<20.0	--	--	--	--	1
	Copper	10.0	--	--	--	--	1
	Iron	170	--	--	--	2,600	2
	Iron, unfiltered	1,000	--	--	--	--	1
Lead	1.0	--	--	--	20.0	2	
Lithium	160	--	--	--	210	2	
Manganese	70.0	--	--	--	450	2	

Appendix E7. Summary statistics for environmental water samples, Great Plains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter; $\mu\text{S}/\text{cm}$, microsiemens per centimeter at 25 degrees Celsius; CaCO_3 , calcium carbonate; N, nitrogen; P, phosphorus]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Madison aquifer— Continued	Manganese, unfiltered	70.0	--	--	--	--	1
	Molybdenum	9.0	--	--	--	13.0	2
	Nickel	1.0	--	--	--	20.0	2
	Strontium	2,300	--	--	--	--	1
	Vanadium	<9.0	--	--	--	--	1
	Zinc	10.0	--	--	--	60.0	2
	Gross beta radioactivity (picocuries per liter)	31.0	--	--	--	51.0	2
	Radium-226 (picocuries per liter)	2.9	--	--	--	--	1
	Tritium, unfiltered (picocuries per liter)	10.0	--	--	--	--	1
	Uranium	2.4	--	--	--	--	1

Appendix F

Summary Statistics for Produced Water Samples

Laura L. Hallberg, and Melanie L. Clark

Appendix F1. Summary statistics for produced-water samples, Sweetwater Arch, Wyoming.

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Consituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Niobrara confining unit	pH (standard units)	8.3	--	--	--	--	1
	Calcium	32.0	--	--	--	--	1
	Magnesium	29.0	--	--	--	--	1
	Sodium	3,170	--	--	--	--	1
	Potassium	20.0	--	--	--	--	1
	Bicarbonate	702	--	--	--	--	1
	Chloride	4,550	--	--	--	--	1
	Sulfate	37.0	--	--	--	--	1
	Total dissolved solids	8,580	--	--	--	--	1
Frontier aquifer	pH (standard units)	7.5	7.9	8.4	8.6	8.6	4
	Calcium	1.0	1.4	10.4	24.0	29.0	4
	Magnesium	10.0	--	--	--	16.0	2
	Sodium	868	1,820	3,110	3,610	3,770	4
	Potassium	11.0	--	28.8	--	339	3
	Bicarbonate	891	1,120	2,290	4,240	5,250	4
	Chloride	150	1,290	3,050	4,180	4,700	4
	Sulfate	9.6	9.8	27.5	181	317	4
	Total dissolved solids	2,150	4,590	8,290	9,830	10,100	4
	Iron	130	--	--	--	6,070	2
Muddy Sandstone aquifer	pH (standard units)	7.3	8.1	8.6	8.9	9.2	6
	Calcium	3.0	12.0	18.0	27.0	50.0	5
	Magnesium	4.0	5.0	7.0	7.0	16.0	5
	Sodium	584	808	1,310	2,550	2,840	6
	Potassium	39.0	--	--	--	--	1
	Bicarbonate	659	1,440	1,650	1,920	2,200	5
	Carbonate	355	--	--	--	--	1
	Chloride	60.0	280	1,010	2,640	4,170	6
	Sulfate	12.0	--	124	--	428	3
	Total dissolved solids	1,520	1,960	3,260	6,700	7,090	6
	Iron	5,350	--	--	--	11,000	2
Cloverly aquifer	pH (standard units)	7.6	--	8.3	--	8.9	3
	Calcium	9.0	--	13.0	--	96.0	3
	Magnesium	2.0	--	3.0	--	6.0	3
	Sodium	534	--	1,370	--	1,860	3
	Potassium	25.0	--	--	--	--	1
	Bicarbonate	366	--	995	--	1,310	3
	Chloride	8.0	--	1,590	--	2,240	3
	Sulfate	19.0	--	28.0	--	712	3
	Total dissolved solids	1,530	--	3,780	--	5,190	3
	Iron	8,200	--	--	--	--	1

2 Appendix F1

Appendix F1. Summary statistics for produced-water samples, Sweetwater Arch, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Morrison confining unit	pH (standard units)	8.8	--	--	--	--	1
	Calcium	21.0	--	--	--	--	1
	Magnesium	12.0	--	--	--	--	1
	Sodium	1,540	--	--	--	--	1
	Potassium	25.0	--	--	--	--	1
	Bicarbonate	646	--	--	--	--	1
	Chloride	1,780	--	--	--	--	1
	Sulfate	55.0	--	--	--	--	1
	Total dissolved solids	4,330	--	--	--	--	1
Nugget aquifer	pH (standard units)	8.5	--	--	--	8.6	2
	Calcium	14.0	--	21.0	--	54.0	3
	Magnesium	1.0	--	5.0	--	29.0	3
	Sodium	327	--	382	--	1,660	3
	Potassium	56.0	--	--	--	--	1
	Bicarbonate	390	--	413	--	738	3
	Chloride	89.0	--	110	--	2,020	3
	Sulfate	70.0	--	390	--	391	3
	Total dissolved solids	1,080	--	1,150	--	4,710	3
Jelm aquifer	pH (standard units)	8.6	--	--	--	--	1
	Calcium	18.0	--	--	--	--	1
	Magnesium	5.0	--	--	--	--	1
	Sodium	674	--	--	--	--	1
	Bicarbonate	815	--	--	--	--	1
	Chloride	50.0	--	--	--	--	1
	Sulfate	568	--	--	--	--	1
	Total dissolved solids	1,840	--	--	--	--	1
	Dinwoody confining unit	pH (standard units)	8.0	--	--	--	--
Calcium		410	--	--	--	--	1
Magnesium		140	--	--	--	--	1
Sodium		1,460	--	--	--	--	1
Potassium		42.0	--	--	--	--	1
Bicarbonate		195	--	--	--	--	1
Chloride		80.0	--	--	--	--	1
Sulfate		4,370	--	--	--	--	1
Total dissolved solids		6,600	--	--	--	--	1

Appendix F1. Summary statistics for produced-water samples, Sweetwater Arch, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Phosphoria aquifer and confining unit	pH (standard units)	6.4	7.5	7.8	8.5	8.9	32
	Calcium	4.0	200	363	533	2,840	35
	Magnesium	3.0	28.0	61.0	105	1,670	34
	Sodium	126	751	1,320	2,020	3,850	35
	Potassium	22.0	32.0	43.5	53.5	59.0	16
	Bicarbonate	134	354	645	1,400	2,950	35
	Chloride	44.0	140	220	339	10,900	35
	Sulfate	644	1,830	2,650	4,000	7,420	35
	Total dissolved solids	1,480	3,700	4,880	7,920	21,800	35
Casper aquifer	pH (standard units)	7.6	--	--	--	--	1
	Calcium	523	--	--	--	--	1
	Magnesium	37.0	--	--	--	--	1
	Sodium	155	--	--	--	--	1
	Bicarbonate	175	--	--	--	--	1
	Chloride	185	--	--	--	--	1
	Sulfate	1,340	--	--	--	--	1
	Total dissolved solids	2,320	--	--	--	--	1
Tensleep aquifer	pH (standard units)	6.7	6.9	7.1	7.9	8.1	9
	Calcium	109	152	219	391	505	12
	Magnesium	12.0	24.5	42.0	54.5	168	12
	Sodium	122	223	347	511	1,570	12
	Potassium	27.0	--	37.0	--	38.0	3
	Bicarbonate	120	195	237	281	656	12
	Chloride	10.0	105	175	293	360	12
	Sulfate	537	662	877	1,650	3,680	12
	Total dissolved solids	1,060	1,440	1,780	2,880	6,250	12
Amsden aquifer	pH (standard units)	8.3	--	--	--	--	1
	Calcium	86.0	--	--	--	--	1
	Magnesium	20.0	--	--	--	--	1
	Sodium	333	--	--	--	--	1
	Bicarbonate	220	--	--	--	--	1
	Chloride	89.0	--	--	--	--	1
	Sulfate	627	--	--	--	--	1
	Total dissolved solids	1,300	--	--	--	--	1

4 Appendix F1

Appendix F1. Summary statistics for produced-water samples, Sweetwater Arch, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Consituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Madison aquifer	pH (standard units)	7.6	--	--	--	8.0	2
	Calcium	78.0	--	--	--	141	2
	Magnesium	9.0	--	--	--	59.0	2
	Sodium	124	--	--	--	316	2
	Potassium	27.0	--	--	--	--	1
	Bicarbonate	106	--	--	--	161	2
	Chloride	103	--	--	--	224	2
	Sulfate	456	--	--	--	580	2
	Total dissolved solids	1,090	--	--	--	1,290	2

Appendix F2. Summary statistics for produced-water samples, central Wyoming basins (south), Wyoming.

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Browns Park aquifer	pH (standard units)	6.5	--	--	--	--	1
	Calcium	34.0	--	--	--	--	1
	Magnesium	38.0	--	--	--	--	1
	Sodium	329	--	--	--	--	1
	Bicarbonate	227	--	--	--	--	1
	Chloride	174	--	--	--	--	1
	Sulfate	602	--	--	--	--	1
	Total dissolved solids	1,290	--	--	--	--	1
Hanna aquifer	pH (standard units)	8.8	--	--	--	8.9	2
	Calcium	23.3	--	--	--	74.5	2
	Magnesium	11.0	--	--	--	45.7	2
	Sodium	835	--	--	--	1,210	2
	Potassium	458	--	--	--	483	2
	Bicarbonate	851	--	--	--	2,090	2
	Carbonate	31.2	--	--	--	55.6	2
	Chloride	109	--	--	--	248	2
	Sulfate	1,380	--	--	--	1,620	2
	Total dissolved solids	4,690	--	--	--	5,150	2
	Iron	640	--	--	--	1,880	2
Fort Union aquifer	pH (standard units)	7.4	--	--	--	--	1
	Calcium	1,780	--	--	--	--	1
	Magnesium	81.0	--	--	--	--	1
	Sodium	2,740	--	--	--	--	1
	Potassium	59.0	--	--	--	--	1
	Bicarbonate	207	--	--	--	--	1
	Chloride	7,400	--	--	--	--	1
	Sulfate	207	--	--	--	--	1
	Total dissolved solids	12,400	--	--	--	--	1
Lewis confining unit	pH (standard units)	8.3	--	8.5	--	8.6	3
	Calcium	3.0	--	11.0	--	16.0	3
	Magnesium	1.0	--	3.0	--	6.0	3
	Sodium	450	--	556	--	841	3
	Potassium	8.0	--	--	--	22.0	2
	Bicarbonate	427	--	564	--	1,320	3
	Chloride	150	--	350	--	420	3
	Sulfate	104	--	119	--	530	3
	Total dissolved solids	1,210	--	1,580	--	2,060	3

2 Appendix F2

Appendix F2. Summary statistics for produced-water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Mesaverde aquifer	pH (standard units)	7.4	7.7	8.2	8.4	8.8	9
	Calcium	4.9	11.0	11.0	12.0	67.0	9
	Magnesium	2.0	2.2	3.9	11.0	55.0	8
	Sodium	327	503	685	860	3,400	9
	Potassium	7.0	8.3	11.2	21.4	30.0	4
	Bicarbonate	610	1,130	1,600	1,950	3,180	8
	Carbonate	24.0	--	--	--	--	1
	Chloride	36.0	42.0	60.0	252	5,030	9
	Sulfate	3.0	15.0	83.5	292	820	8
	Total dissolved solids	1,090	1,360	1,710	2,130	11,200	9
	Iron	110	--	1,210	--	17,000	3
Cody confining unit	pH (standard units)	8.5	--	--	--	--	1
	Calcium	8.0	--	--	--	--	1
	Magnesium	3.0	--	--	--	--	1
	Sodium	640	--	--	--	--	1
	Potassium	13.0	--	--	--	--	1
	Bicarbonate	1,440	--	--	--	--	1
	Chloride	128	--	--	--	--	1
	Total dissolved solids	1,550	--	--	--	--	1
Shannon Sandstone Member of the Cody Shale	pH (standard units)	8.2	--	--	--	8.3	2
	Calcium	18.0	--	--	--	50.0	2
	Magnesium	8.0	--	--	--	18.0	2
	Sodium	2,990	--	--	--	6,870	2
	Bicarbonate	1,290	--	--	--	1,520	2
	Chloride	3,900	--	--	--	9,700	2
	Sulfate	16.0	--	--	--	21.0	2
	Total dissolved solids	7,570	--	--	--	17,500	2
Steele confining unit	pH (standard units)	7.8	--	--	--	8.3	2
	Calcium	4.0	--	--	--	43.0	2
	Magnesium	7.0	--	--	--	16.0	2
	Sodium	775	--	--	--	4,360	2
	Potassium	25.0	--	--	--	--	1
	Bicarbonate	988	--	--	--	1,860	2
	Chloride	43.0	--	--	--	6,030	2
	Sulfate	121	--	--	--	340	2
	Total dissolved solids	1,910	--	--	--	11,800	2

Appendix F2. Summary statistics for produced-water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Niobrara confining unit	pH (standard units)	7.2	7.4	7.8	8.4	9.7	9
	Calcium	18.0	50.0	326	414	670	9
	Magnesium	6.0	32.0	86.9	171	261	8
	Sodium	475	2,620	11,200	12,300	22,300	9
	Potassium	15.0	57.7	59.0	104	120	6
	Bicarbonate	313	537	699	1,240	1,320	8
	Carbonate	480	--	--	--	--	1
	Chloride	550	3,300	17,300	20,800	32,300	9
	Sulfate	15.0	22.0	213	1,120	2,380	7
	Total dissolved solids	4,360	6,950	29,000	31,100	57,500	9
	Iron	50.0	--	--	--	132,000	2
Frontier aquifer	pH (standard units)	6.2	7.7	8.0	8.6	9.0	24
	Calcium	9.0	17.0	37.0	154	986	26
	Magnesium	0.50	9.0	10.0	48.0	390	25
	Sodium	1,260	3,620	4,540	5,300	17,200	26
	Potassium	17.0	20.0	41.4	78.0	134	16
	Bicarbonate	130	549	805	1,820	4,640	26
	Carbonate	60.0	--	--	--	144	2
	Chloride	1,340	4,150	5,680	10,400	29,000	26
	Sulfate	1.0	6.2	61.0	133	931	23
	Total dissolved solids	3,210	9,270	12,200	17,300	47,600	26
	Iron	40.0	--	--	--	1,000	2
Muddy Sandstone aquifer	pH (standard units)	5.9	7.8	8.1	8.5	8.9	36
	Calcium	2.0	13.0	19.5	39.0	203	38
	Magnesium	1.0	4.0	6.0	15.0	77.0	37
	Sodium	531	1,330	2,440	3,040	6,900	40
	Potassium	4.0	5.0	10.0	20.0	38.0	23
	Bicarbonate	232	1,060	1,200	1,710	3,250	40
	Carbonate	192	--	--	--	--	1
	Chloride	70.0	455	2,340	3,950	9,310	40
	Sulfate	4.0	16.5	113	401	5,740	36
	Total dissolved solids	1,380	3,480	6,250	8,280	18,300	40
Cloverly aquifer	pH (standard units)	6.3	7.9	8.3	8.5	8.9	64
	Calcium	2.0	10.0	20.0	42.4	536	69
	Magnesium	1.0	4.0	8.0	16.0	95.0	62
	Sodium	371	849	1,770	3,050	9,000	72
	Potassium	3.0	6.0	14.0	25.0	58.0	26
	Bicarbonate	49.0	903	1,160	1,350	3,730	72
	Carbonate	60.0	--	--	--	336	2
	Chloride	18.0	317	1,910	3,700	14,300	72
	Sulfate	1.0	28.0	139	505	5,410	66
	Total dissolved solids	1,020	2,220	4,730	7,970	24,100	72
	Iron	12,700	--	--	--	35,400	2

4 Appendix F2

Appendix F2. Summary statistics for produced-water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Morrison confining unit	pH (standard units)	7.9	8.2	8.2	8.3	8.9	5
	Calcium	16.0	22.0	24.0	31.0	169	5
	Magnesium	2.0	3.0	5.0	6.0	7.0	5
	Sodium	1,160	1,290	1,820	1,830	4,330	5
	Potassium	16.0	--	--	--	--	1
	Bicarbonate	939	1,090	1,160	1,710	2,240	5
	Chloride	200	200	1,560	2,260	5,400	5
	Sulfate	30.0	34.0	714	1,220	1,530	5
	Total dissolved solids	3,010	3,680	5,170	5,350	10,900	5
Sundance aquifer	pH (standard units)	8.0	8.2	8.3	8.7	8.8	17
	Calcium	2.0	5.0	17.0	39.0	1,290	18
	Magnesium	1.0	2.0	3.0	10.0	123	17
	Sodium	429	575	881	1,190	45,600	18
	Potassium	6.0	10.0	16.0	44.0	80.0	5
	Bicarbonate	500	920	1,090	1,250	1,950	17
	Chloride	28.0	130	178	408	64,000	18
	Sulfate	10.0	86.0	430	1,230	12,100	18
	Total dissolved solids	1,040	1,440	2,240	3,480	123,000	18
Nugget aquifer	pH (standard units)	6.7	7.5	8.1	8.3	9.1	14
	Calcium	4.0	14.5	19.0	33.0	731	16
	Magnesium	1.0	5.0	7.9	23.0	141	14
	Sodium	732	1,560	1,850	3,340	5,200	16
	Potassium	16.0	19.5	26.0	37.5	46.0	4
	Bicarbonate	98.0	908	1,090	2,220	5,270	16
	Carbonate	528	--	--	--	--	1
	Chloride	150	620	2,140	4,190	8,910	16
	Sulfate	6.0	91.0	105	410	950	14
	Total dissolved solids	1,900	3,890	4,900	8,550	16,000	16
	Iron	80.0	--	--	--	7,400	2
Phosphoria aquifer and confining unit	pH (standard units)	6.8	7.3	8.0	8.1	9.1	9
	Calcium	65.0	133	330	866	1,760	11
	Magnesium	9.0	24.0	42.0	125	762	11
	Sodium	170	541	1,600	2,600	4,800	11
	Potassium	10.0	--	--	--	28.0	2
	Bicarbonate	65.0	340	590	769	1,140	11
	Carbonate	96.0	--	--	--	--	1
	Chloride	24.0	377	844	3,240	7,130	11
	Sulfate	30.0	638	2,800	4,210	5,240	11
Total dissolved solids	1,610	3,240	8,080	10,500	16,400	11	

Appendix F2. Summary statistics for produced-water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Forelle aquifer	pH (standard units)	8.2	--	--	--	8.5	2
	Calcium	813	--	--	--	813	2
	Magnesium	189	--	--	--	205	2
	Sodium	26,200	--	--	--	27,600	2
	Bicarbonate	60.0	--	--	--	170	2
	Chloride	32,000	--	--	--	34,000	2
	Sulfate	14,100	--	--	--	14,200	2
	Total dissolved solids	73,400	--	--	--	76,900	2
Casper aquifer	pH (standard units)	5.2	7.5	7.8	8.2	8.9	52
	Calcium	15.0	291	425	630	1,970	55
	Magnesium	10.0	33.0	66.0	104	454	53
	Sodium	424	807	1,810	4,640	27,800	55
	Potassium	13.0	44.0	86.0	220	332	11
	Bicarbonate	60.0	171	270	510	2,200	55
	Chloride	58.0	410	980	4,450	42,900	55
	Sulfate	195	1,970	2,840	3,920	10,200	55
	Total dissolved solids	2,320	3,930	7,630	13,600	75,900	55
Tensleep aquifer	pH (standard units)	6.4	7.2	7.6	8.0	8.4	16
	Calcium	78.0	220	349	580	1,620	20
	Magnesium	10.0	24.0	55.0	86.0	836	19
	Sodium	365	1,130	1,900	2,740	7,990	20
	Potassium	17.0	38.5	62.1	161	258	4
	Bicarbonate	180	329	842	1,760	3,120	19
	Chloride	45.0	464	980	3,450	13,400	20
	Sulfate	18.5	1,700	2,190	3,460	5,510	20
	Total dissolved solids	1,300	5,060	7,480	10,500	23,300	20
	Iron	50.0	--	--	--	--	1
Amsden aquifer	pH (standard units)	6.9	--	7.2	--	8.2	3
	Calcium	299	--	381	--	403	3
	Magnesium	29.0	--	55.0	--	61.0	3
	Sodium	1,810	--	2,540	--	5,420	3
	Potassium	223	--	--	--	--	1
	Bicarbonate	886	--	1,190	--	2,190	3
	Chloride	1,630	--	2,150	--	4,120	3
	Sulfate	2,140	--	2,910	--	4,680	3
	Total dissolved solids	6,480	--	9,450	--	15,700	3

6 Appendix F2

Appendix F2. Summary statistics for produced-water samples, central Wyoming basins (south), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Madison aquifer	pH (standard units)	7.2	--	7.5	--	9.0	3
	Calcium	213	--	257	--	289	3
	Magnesium	34.0	--	56.0	--	111	3
	Sodium	411	--	652	--	2,170	3
	Potassium	20.0	--	--	--	--	1
	Bicarbonate	244	--	282	--	1,250	3
	Chloride	412	--	495	--	2,000	3
	Sulfate	32.0	--	1,300	--	2,450	3
	Total dissolved solids	2,140	--	2,880	--	7,070	3
Aquifers in undifferentiated Cambrian rocks	pH (standard units)	7.6	--	--	--	--	1
	Calcium	459	--	--	--	--	1
	Magnesium	74.0	--	--	--	--	1
	Sodium	1,540	--	--	--	--	1
	Potassium	181	--	--	--	--	1
	Bicarbonate	707	--	--	--	--	1
	Chloride	1,620	--	--	--	--	1
	Sulfate	2,140	--	--	--	--	1
	Total dissolved solids	6,680	--	--	--	--	1
Flathead aquifer	pH (standard units)	7.2	--	--	--	--	1
	Calcium	247	--	--	--	--	1
	Magnesium	6.0	--	--	--	--	1
	Sodium	1,060	--	--	--	--	1
	Potassium	34.0	--	--	--	--	1
	Bicarbonate	110	--	--	--	--	1
	Chloride	730	--	--	--	--	1
	Sulfate	1,800	--	--	--	--	1
	Total dissolved solids	3,930	--	--	--	--	1

1 Appendix F3

Appendix F3. Summary statistics for produced-water samples, Medicine Bow Mountains, Wyoming.

[--, not applicable]

Hydrogeologic unit	Consituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Casper aquifer	pH (standard units)	7.8	--	--	--	--	1
	Calcium	559	--	--	--	--	1
	Magnesium	140	--	--	--	--	1
	Sodium	537	--	--	--	--	1
	Potassium	10.0	--	--	--	--	1
	Bicarbonate	171	--	--	--	--	1
	Chloride	160	--	--	--	--	1
	Sulfate	2,680	--	--	--	--	1
	Total dissolved solids	4,170	--	--	--	--	1

1 Appendix F4

Appendix F4. Summary statistics for produced-water samples, Laramie Mountains, Wyoming.

[--, not applicable]

Hydrogeologic unit	Character or constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Muddy Sandstone aquifer	pH (standard units)	8.7	--	--	--	--	1
	Calcium	6.0	--	--	--	--	1
	Magnesium	2.0	--	--	--	--	1
	Sodium	995	--	--	--	--	1
	Potassium	8.0	--	--	--	--	1
	Bicarbonate	1,260	--	--	--	--	1
	Chloride	50.0	--	--	--	--	1
	Sulfate	900	--	--	--	--	1
	Total dissolved solids	2,680	--	--	--	--	1
Cloverly aquifer	pH (standard units)	8.6	--	--	--	--	1
	Calcium	5.0	--	--	--	--	1
	Magnesium	1.0	--	--	--	--	1
	Sodium	509	--	--	--	--	1
	Potassium	6.0	--	--	--	--	1
	Bicarbonate	1,230	--	--	--	--	1
	Chloride	16.0	--	--	--	--	1
	Total dissolved solids	1,200	--	--	--	--	1

Appendix F5. Summary statistics for produced-water samples, central Wyoming basins (north), Wyoming.

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Consituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Lance aquifer	pH (standard units)	7.6	8.2	8.4	8.5	8.6	5
	Calcium	7.0	7.0	19.5	33.0	57.0	6
	Magnesium	1.0	2.0	8.0	20.5	28.0	4
	Sodium	345	459	605	1,100	1,300	6
	Potassium	5.0	9.0	11.0	13.0	28.0	5
	Bicarbonate	403	451	628	805	1,810	6
	Chloride	25.0	72.0	155	370	1,150	6
	Sulfate	489	493	528	570	769	6
	Total dissolved solids	1,220	1,300	1,710	3,020	3,410	6
Fox Hills aquifer	pH (standard units)	8.3	--	--	--	--	1
	Calcium	5.0	--	--	--	--	1
	Magnesium	1.0	--	--	--	--	1
	Sodium	356	--	--	--	--	1
	Potassium	10.0	--	--	--	--	1
	Bicarbonate	458	--	--	--	--	1
	Carbonate	30.0	--	--	--	--	1
	Sulfate	270	--	--	--	--	1
	Total dissolved solids	1,180	--	--	--	--	1
Mesaverde aquifer	pH (standard units)	7.9	--	8.3	--	8.9	3
	Calcium	10.0	--	16.0	--	35.0	3
	Magnesium	1.0	--	3.0	--	3.0	3
	Sodium	1,160	--	1,220	--	1,600	3
	Potassium	12.0	--	33.0	--	35.0	3
	Bicarbonate	1,180	--	1,680	--	2,150	3
	Chloride	230	--	1,000	--	1,030	3
	Sulfate	318	--	329	--	539	3
	Total dissolved solids	2,880	--	3,210	--	4,190	3
Teapot Sandstone Member of the Mesaverde Formation	pH (standard units)	7.0	--	8.0	--	8.5	3
	Calcium	4.0	--	8.0	--	12.0	3
	Magnesium	1.0	--	1.0	--	5.0	3
	Sodium	483	--	560	--	634	3
	Potassium	5.0	--	6.0	--	7.0	3
	Bicarbonate	915	--	927	--	976	3
	Chloride	42.0	--	64.0	--	176	3
	Sulfate	183	--	244	--	525	3
	Total dissolved solids	1,240	--	1,420	--	1,730	3

2 Appendix F5

Appendix F5. Summary statistics for produced-water samples, central Wyoming basins (north), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Consituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Parkman Sandstone Member of the Mesaverde Formation	pH (standard units)	8.2	--	8.3	--	8.8	3
	Calcium	2.0	--	3.0	--	12.0	3
	Magnesium	1.0	--	--	--	5.0	2
	Sodium	587	591	636	1,320	1,960	4
	Potassium	3.0	--	16.0	--	50.0	3
	Bicarbonate	583	1,030	1,550	2,200	2,780	4
	Carbonate	403	--	--	--	--	1
	Chloride	32.0	36.5	52.5	520	975	4
	Sulfate	16.0	20.0	42.0	397	733	4
	Total dissolved solids	1,370	1,520	1,660	3,220	4,780	4
Shannon Sandstone Member of the Cody Shale	pH (standard units)	5.8	7.2	8.0	8.4	8.8	14
	Calcium	6.0	30.0	47.0	78.0	5,850	25
	Magnesium	2.0	14.5	20.5	48.5	2,900	24
	Sodium	478	3,660	6,110	6,930	9,840	25
	Potassium	15.0	27.0	35.0	48.0	240	9
	Bicarbonate	146	533	800	1,390	2,730	25
	Carbonate	241	--	--	--	--	1
	Chloride	280	5,420	9,200	9,900	31,000	25
	Sulfate	15.0	70.0	108	306	2,780	12
	Total dissolved solids	1,280	9,820	15,700	18,000	48,000	25
Niobrara confining unit	pH (standard units)	8.0	--	--	--	8.2	2
	Calcium	20.0	--	--	--	28.0	2
	Magnesium	10.0	--	--	--	12.0	2
	Sodium	2,350	--	--	--	4,150	2
	Potassium	24.0	--	--	--	--	1
	Bicarbonate	1,150	--	--	--	4,560	2
	Chloride	2,700	--	--	--	3,840	2
	Sulfate	457	--	--	--	--	1
	Total dissolved solids	6,120	--	--	--	10,300	2
Frontier aquifer	pH (standard units)	6.0	7.8	8.2	8.4	9.2	22
	Calcium	8.0	11.0	15.0	97.4	2,160	21
	Magnesium	2.0	3.0	8.5	18.0	148	22
	Sodium	830	1,540	2,800	5,860	10,200	22
	Potassium	3.0	15.5	22.5	67.5	840	16
	Bicarbonate	510	1,230	1,480	2,000	6,830	22
	Carbonate	360	--	--	--	--	1
	Chloride	64.0	650	3,020	6,350	19,800	22
	Sulfate	3.0	76.5	241	824	3,480	20
	Total dissolved solids	2,260	4,630	6,850	15,400	34,100	22
	Iron	40.0	--	--	--	--	1

Appendix F5. Summary statistics for produced-water samples, central Wyoming basins (north), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Consituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Wall Creek Sandstone Member of the Frontier Formation	pH (standard units)	6.5	8.3	8.4	8.5	8.7	36
	Calcium	3.0	3.0	6.0	17.5	653	40
	Magnesium	1.0	1.0	2.0	4.5	92.0	40
	Sodium	601	1,060	1,210	1,500	7,210	40
	Potassium	3.0	5.0	5.0	8.0	37.0	28
	Bicarbonate	310	1,460	1,840	2,150	3,680	40
	Carbonate	182	--	--	--	--	1
	Chloride	63.0	440	575	878	9,300	40
	Sulfate	7.0	22.0	148	646	1,450	26
	Total dissolved solids	2,300	2,750	3,010	3,870	18,300	40
Muddy Sandstone aquifer	pH (standard units)	6.8	7.7	8.0	8.3	8.7	51
	Calcium	3.0	16.0	32.0	50.0	130	51
	Magnesium	1.0	7.0	9.0	17.0	62.0	49
	Sodium	521	1,460	3,420	4,570	6,440	51
	Potassium	3.0	5.0	12.0	19.0	40.0	13
	Bicarbonate	659	1,580	2,330	2,900	5,960	51
	Carbonate	108	--	--	--	--	1
	Chloride	40.0	620	2,780	5,720	8,600	51
	Sulfate	2.0	23.0	62.0	206	1,330	46
	Total dissolved solids	1,360	3,700	8,490	11,900	16,700	51
	Iron	54,000	--	--	--	--	1
Cloverly aquifer	pH (standard units)	5.8	7.6	8.1	8.3	8.8	100
	Calcium	2.0	8.7	17.5	56.0	1,220	102
	Magnesium	1.0	2.0	8.5	19.0	270	90
	Sodium	119	805	1,440	3,820	7,170	104
	Potassium	2.0	6.0	10.0	18.5	640	44
	Bicarbonate	73.0	990	1,490	1,890	3,070	103
	Carbonate	38.0	--	--	--	--	1
	Chloride	12.0	295	1,050	3,550	11,200	104
	Sulfate	3.0	76.0	241	633	11,000	100
	Total dissolved solids	1,040	2,050	3,730	10,200	19,600	104
	Iron	50.0	--	170	--	500	3
Morrison confining unit	pH (standard units)	7.0	--	--	--	--	1
	Calcium	489	--	--	--	--	1
	Magnesium	5.0	--	--	--	--	1
	Sodium	6,590	--	--	--	--	1
	Bicarbonate	620	--	--	--	--	1
	Chloride	9,400	--	--	--	--	1
	Sulfate	1,760	--	--	--	--	1
	Total dissolved solids	18,600	--	--	--	--	1

4 Appendix F5

Appendix F5. Summary statistics for produced-water samples, central Wyoming basins (north), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Sundance aquifer	pH (standard units)	6.3	7.8	8.3	8.7	8.9	15
	Calcium	4.0	7.0	11.0	154	507	17
	Magnesium	2.0	3.0	6.0	31.0	143	15
	Sodium	448	724	864	1,010	5,210	17
	Potassium	5.0	7.0	10.0	10.0	20.0	10
	Bicarbonate	122	610	939	1,160	1,680	17
	Chloride	30.0	148	200	510	2,120	17
	Sulfate	109	325	680	1,270	7,900	17
	Total dissolved solids	1,170	2,100	2,460	3,960	16,600	17
Nugget aquifer	pH (standard units)	8.2	--	--	--	--	1
	Calcium	3.0	--	--	--	--	1
	Sodium	677	--	--	--	--	1
	Bicarbonate	940	--	--	--	--	1
	Chloride	98.0	--	--	--	--	1
	Sulfate	492	--	--	--	--	1
	Total dissolved solids	1,770	--	--	--	--	1
Chugwater aquifer and confining unit	pH (standard units)	8.2	--	--	--	8.3	2
	Calcium	18.0	--	--	--	18.0	2
	Magnesium	5.0	--	--	--	13.0	2
	Sodium	980	--	--	--	1,260	2
	Bicarbonate	440	--	--	--	540	2
	Chloride	240	--	--	--	298	2
	Sulfate	1,240	--	--	--	1,920	2
	Total dissolved solids	2,830	--	--	--	3,760	2
Phosphoria aquifer and confining unit	pH (standard units)	7.9	--	--	--	--	1
	Calcium	541	--	--	--	--	1
	Magnesium	162	--	--	--	--	1
	Sodium	6,990	--	--	--	--	1
	Potassium	100	--	--	--	--	1
	Bicarbonate	549	--	--	--	--	1
	Chloride	5,100	--	--	--	--	1
	Sulfate	9,350	--	--	--	--	1
	Total dissolved solids	22,500	--	--	--	--	1

Appendix F5. Summary statistics for produced-water samples, central Wyoming basins (north), Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Consituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Casper aquifer	pH (standard units)	7.0	7.5	7.6	8.0	8.1	5
	Calcium	239	280	408	579	584	7
	Magnesium	3.0	25.0	64.0	105	132	7
	Sodium	427	442	544	930	3,070	7
	Potassium	104	--	--	--	--	1
	Bicarbonate	110	110	170	281	537	7
	Chloride	27.0	50.0	361	512	640	7
	Sulfate	1,370	1,380	2,020	3,440	7,110	7
	Total dissolved solids	2,660	2,940	3,310	5,220	11,200	7
Tensleep aquifer	pH (standard units)	6.5	7.3	7.7	8.0	8.7	45
	Calcium	19.0	211	288	392	618	54
	Magnesium	11.0	50.0	71.0	87.0	223	54
	Sodium	26.0	356	438	607	5,410	54
	Potassium	10.0	20.0	23.0	32.0	37.0	13
	Bicarbonate	20.0	163	243	464	1,350	54
	Chloride	12.0	304	360	411	1,700	54
	Sulfate	79.0	782	1,210	1,720	10,300	54
	Total dissolved solids	1,030	2,080	2,490	3,190	18,400	54
Amsden aquifer	pH (standard units)	7.5	--	--	--	--	1
	Calcium	527	--	--	--	--	1
	Magnesium	131	--	--	--	--	1
	Sodium	409	--	--	--	--	1
	Bicarbonate	127	--	--	--	--	1
	Chloride	364	--	--	--	--	1
	Sulfate	2,040	--	--	--	--	1
	Total dissolved solids	3,540	--	--	--	--	1
Madison aquifer	pH (standard units)	6.2	6.4	6.8	7.2	7.8	8
	Calcium	20.0	174	256	374	500	10
	Magnesium	20.0	37.0	55.0	59.0	66.0	9
	Sodium	171	521	572	921	2,410	10
	Potassium	16.0	40.0	47.0	64.0	99.0	6
	Bicarbonate	146	193	195	268	1,030	10
	Chloride	126	250	430	600	1,180	10
	Sulfate	106	875	1,290	1,570	3,910	10
	Total dissolved solids	1,220	1,940	3,160	3,770	7,770	10

Appendix F6. Summary statistics for produced-water samples, Great Plains, Wyoming.

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Consituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Fort Union aquifer	pH (standard units)	7.3	--	--	--	--	1
	Calcium	71.0	--	--	--	--	1
	Magnesium	34.0	--	--	--	--	1
	Sodium	61.0	--	--	--	--	1
	Potassium	10.0	--	--	--	--	1
	Bicarbonate	342	--	--	--	--	1
	Chloride	8.0	--	--	--	--	1
	Sulfate	181	--	--	--	--	1
	Total dissolved solids	533	--	--	--	--	1
Lance aquifer	pH (standard units)	6.4	8.1	8.3	8.5	8.8	20
	Calcium	2.0	7.5	14.0	19.5	1,310	20
	Magnesium	1.0	3.0	4.0	8.0	446	17
	Sodium	387	513	629	814	1,670	20
	Potassium	8.0	--	10.0	--	20.0	3
	Bicarbonate	171	769	1,010	1,230	1,960	20
	Chloride	60.0	145	210	316	6,000	20
	Sulfate	4.0	50.0	62.0	176	360	20
	Total dissolved solids	1,010	1,300	1,540	2,050	9,620	20
Lewis confining unit	pH (standard units)	7.2	--	--	--	--	1
	Calcium	26.0	--	--	--	--	1
	Magnesium	9.0	--	--	--	--	1
	Sodium	3,260	--	--	--	--	1
	Potassium	59.0	--	--	--	--	1
	Bicarbonate	659	--	--	--	--	1
	Chloride	4,750	--	--	--	--	1
	Sulfate	25.0	--	--	--	--	1
	Total dissolved solids	8,450	--	--	--	--	1
Mesaverde aquifer	pH (standard units)	7.0	--	--	--	8.2	2
	Calcium	26.0	--	--	--	74.0	2
	Magnesium	13.0	--	--	--	14.0	2
	Sodium	1,920	--	--	--	5,980	2
	Bicarbonate	1,410	--	--	--	1,930	2
	Chloride	1,350	--	--	--	8,490	2
	Sulfate	116	--	--	--	704	2
	Total dissolved solids	5,010	--	--	--	15,400	2

2 Appendix F6

Appendix F6. Summary statistics for produced-water samples, Great Plains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Teapot Sandstone Member of the Mesaverde Formation	pH (standard units)	7.0	7.5	7.7	8.2	8.4	16
	Calcium	10.0	85.0	123	228	1,250	17
	Magnesium	1.0	15.0	22.0	43.0	271	17
	Sodium	1,160	4,560	5,240	5,900	6,490	17
	Potassium	10.0	29.0	46.5	96.5	460	12
	Bicarbonate	451	1,030	1,150	1,390	1,620	17
	Carbonate	48.0	--	--	--	--	1
	Chloride	840	6,300	8,000	9,100	9,900	17
	Sulfate	10.0	32.0	58.0	122	358	13
	Total dissolved solids	2,880	12,000	14,400	16,000	17,200	17
	Iron	1,000	--	--	--	--	1
Parkman Sandstone Member of the Mesaverde Formation	pH (standard units)	7.0	7.5	8.4	8.9	8.9	4
	Calcium	16.0	19.5	60.5	127	156	4
	Magnesium	4.0	4.0	9.0	17.0	20.0	4
	Sodium	1,010	1,660	3,950	6,240	6,890	4
	Potassium	29.0	--	35.0	--	450	3
	Bicarbonate	988	1,240	1,680	1,990	2,130	4
	Chloride	1,100	1,680	5,350	8,930	9,420	4
	Sulfate	21.0	--	190	--	218	3
	Total dissolved solids	3,140	4,490	11,000	16,800	17,400	4
	Iron	37,000	--	--	--	--	1
	Niobrara confining unit	pH (standard units)	6.1	6.9	7.2	7.9	8.6
Calcium		10.0	37.0	78.5	234	5,110	42
Magnesium		4.0	12.0	36.0	83.2	373	41
Sodium		1,020	4,310	10,800	17,500	43,700	42
Potassium		13.0	--	100	--	1,240	3
Bicarbonate		146	584	774	1,010	1,840	42
Carbonate		105	--	--	--	--	1
Chloride		1,470	6,350	16,300	27,500	67,300	42
Sulfate		1.0	20.0	25.0	42.5	322	28
Total dissolved solids		3,550	11,600	27,200	46,600	112,000	42
Iron		1,000	5,000	10,000	24,000	88,000	15
Frontier aquifer	pH (standard units)	5.6	6.2	6.6	7.3	9.1	11
	Calcium	15.0	404	1,030	5,560	16,800	11
	Magnesium	5.0	51.0	90.0	345	1,340	11
	Sodium	202	1,530	11,400	15,000	16,000	11
	Potassium	33.0	104	600	3,850	12,300	9
	Bicarbonate	153	451	573	803	2,440	11
	Carbonate	60.0	--	--	--	--	1
	Chloride	209	18,200	24,800	33,700	57,200	11
	Sulfate	5.0	8.0	13.0	61.0	97.0	6
	Total dissolved solids	691	27,000	41,200	60,800	91,600	11
	Iron	12,000	52,000	60,500	69,100	140,000	6

Appendix F6. Summary statistics for produced-water samples, Great Plains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Wall Creek Sandstone Member of the Frontier Formation	pH (standard units)	8.2	--	--	--	8.6	2
	Calcium	5.0	--	--	--	6.0	2
	Magnesium	1.0	--	--	--	1.0	2
	Sodium	1,410	--	--	--	1,430	2
	Potassium	6.0	--	--	--	7.0	2
	Bicarbonate	3,090	--	--	--	3,140	2
	Chloride	360	--	--	--	396	2
	Sulfate	62.0	--	--	--	--	1
	Total dissolved solids	3,340	--	--	--	3,410	2
Greenhorn confining unit	pH (standard units)	8.6	--	--	--	--	1
	Calcium	19.0	--	--	--	--	1
	Magnesium	2.0	--	--	--	--	1
	Sodium	766	--	--	--	--	1
	Potassium	10.0	--	--	--	--	1
	Bicarbonate	1,150	--	--	--	--	1
	Chloride	150	--	--	--	--	1
	Sulfate	387	--	--	--	--	1
	Total dissolved solids	2,010	--	--	--	--	1
Muddy Sandstone aquifer	pH (standard units)	5.7	7.5	8.0	8.4	9.1	31
	Calcium	8.0	23.0	48.0	139	194	31
	Magnesium	2.0	8.5	16.0	39.5	1,550	28
	Sodium	462	2,470	4,190	7,620	19,300	31
	Potassium	5.0	11.5	25.0	35.5	515	16
	Bicarbonate	403	854	1,090	1,500	2,210	31
	Carbonate	20.0	40.0	66.0	228	384	4
	Chloride	60.0	2,880	5,700	12,000	28,800	31
	Sulfate	25.0	29.0	128	511	8,820	21
	Total dissolved solids	1,240	6,920	11,000	20,500	50,300	31
	Iron	100	--	--	--	400	2
Cloverly aquifer	pH (standard units)	7.7	--	--	--	--	1
	Calcium	66.0	--	--	--	--	1
	Magnesium	24.0	--	--	--	--	1
	Sodium	3,470	--	--	--	--	1
	Potassium	31.0	--	--	--	--	1
	Bicarbonate	1,830	--	--	--	--	1
	Chloride	4,440	--	--	--	--	1
	Sulfate	92.0	--	--	--	--	1
	Total dissolved solids	9,030	--	--	--	--	1

4 Appendix F6

Appendix F6. Summary statistics for produced-water samples, Great Plains, Wyoming.—Continued

[--, not applicable. Values in black are in milligrams per liter unless otherwise noted; values in blue are in micrograms per liter]

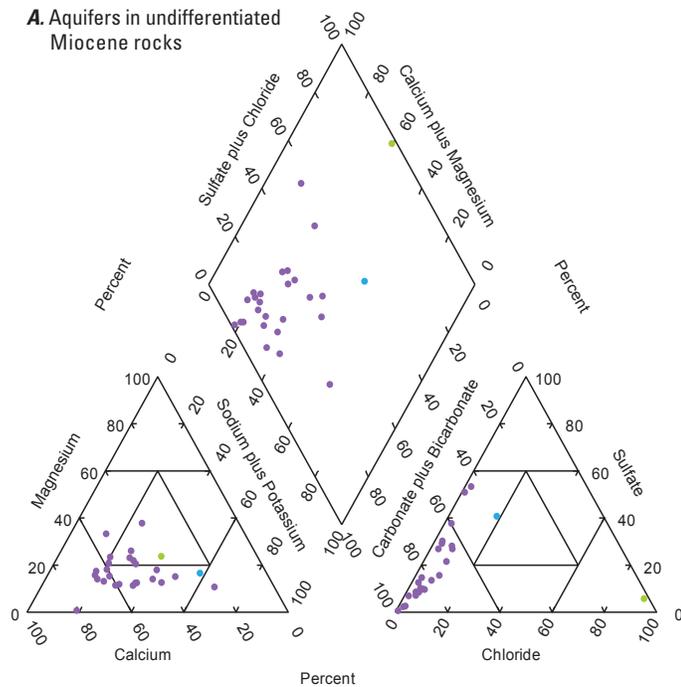
Hydrogeologic unit	Constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Sundance aquifer	pH (standard units)	8.2	--	--	--	8.6	2
	Calcium	51.0	--	--	--	64.0	2
	Magnesium	24.0	--	--	--	27.0	2
	Sodium	827	--	--	--	1,230	2
	Potassium	11.0	--	--	--	40.0	2
	Bicarbonate	586	--	--	--	915	2
	Chloride	140	--	--	--	370	2
	Sulfate	1,080	--	--	--	1,850	2
	Total dissolved solids	2,680	--	--	--	3,830	2
Casper aquifer	Calcium	592	--	--	--	--	1
	Magnesium	207	--	--	--	--	1
	Sodium	211	--	--	--	--	1
	Bicarbonate	150	--	--	--	--	1
	Chloride	105	--	--	--	--	1
	Sulfate	2,420	--	--	--	--	1
	Total dissolved solids	3,680	--	--	--	--	1
Hartville aquifer	pH (standard units)	7.2	--	7.9	--	8.1	3
	Calcium	222	--	322	--	770	3
	Magnesium	51.0	--	79.0	--	83.0	3
	Sodium	590	--	1,000	--	1,430	3
	Bicarbonate	183	--	296	--	854	3
	Chloride	54.0	--	106	--	361	3
	Sulfate	1,810	--	2,340	--	4,410	3
	Total dissolved solids	2,900	--	4,220	--	7,600	3

Appendix G

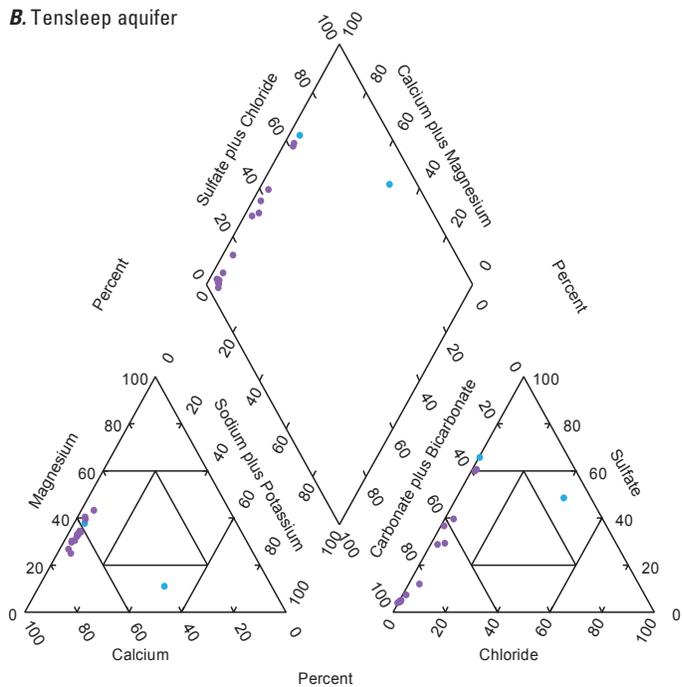
Trilinear Diagrams for Environmental Water Samples

Laura L. Hallberg, and Melanie L. Clark

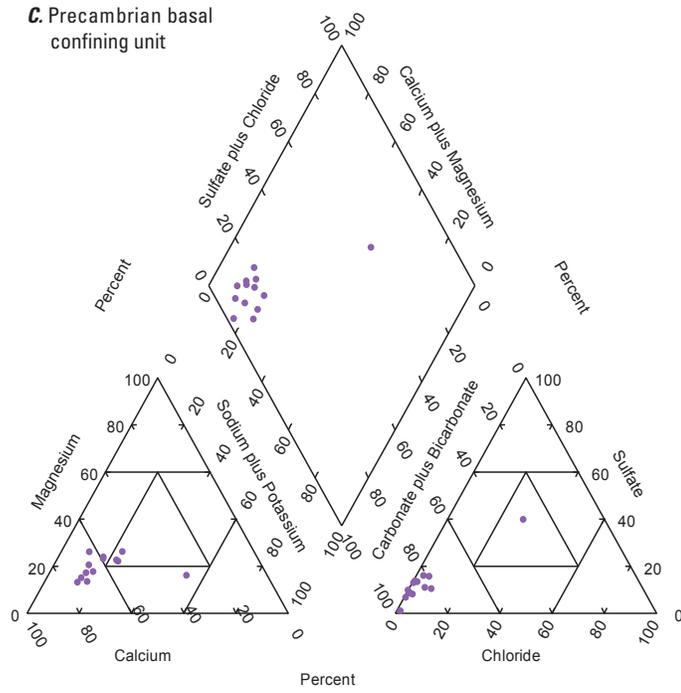
A. Aquifers in undifferentiated Miocene rocks



B. Tensleep aquifer



C. Precambrian basal confining unit



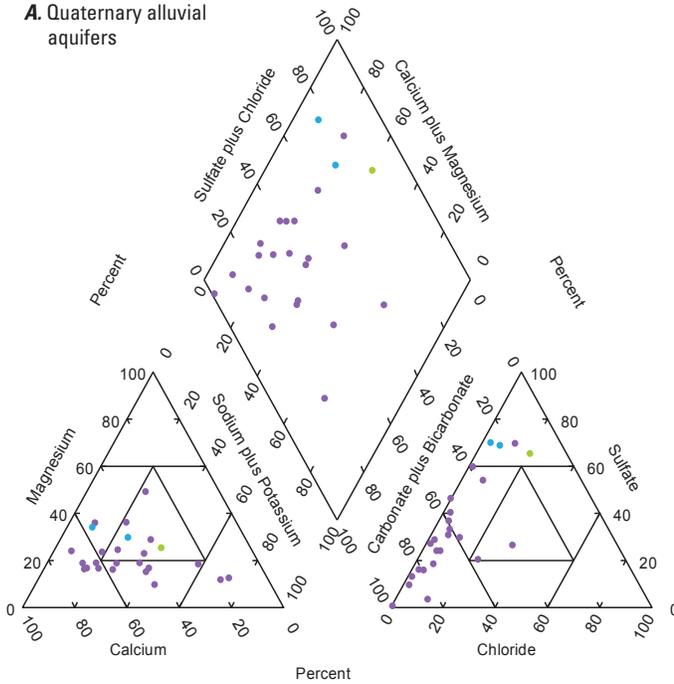
EXPLANATION

Total dissolved-solids concentration, in milligrams per liter, and U.S. Geological Survey salinity classification (Heath, 1983)

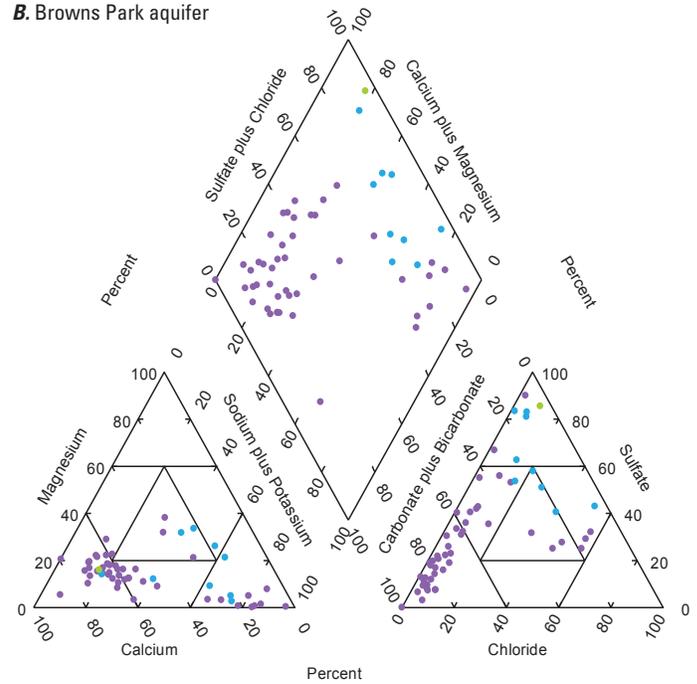
- Less than or equal to 999; fresh
- 1,000–2,999; slightly saline
- 3,000–9,999; moderately saline
- 10,000–34,999; very saline
- Greater than or equal to 35,000; briny

Appendix G1. Trilinear diagrams showing major-ion composition and total dissolved-solids concentrations for environmental groundwater samples from the Sweetwater Arch.

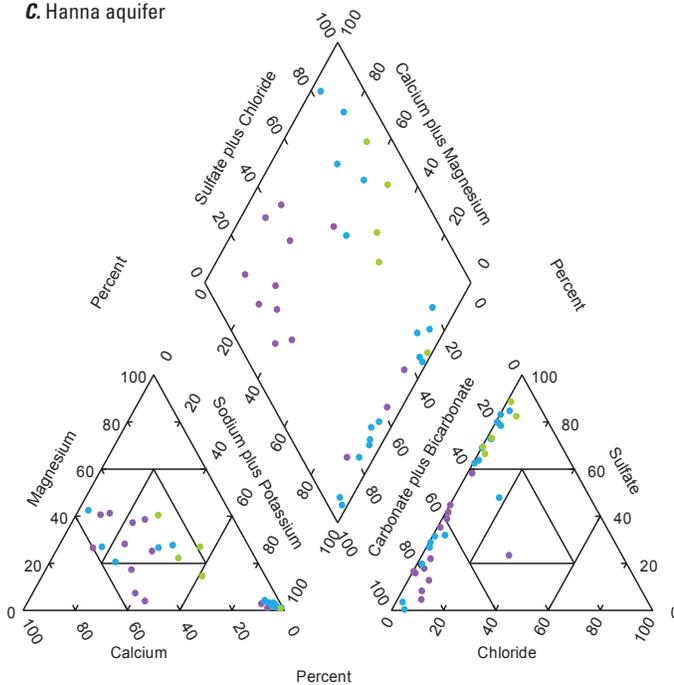
A. Quaternary alluvial aquifers



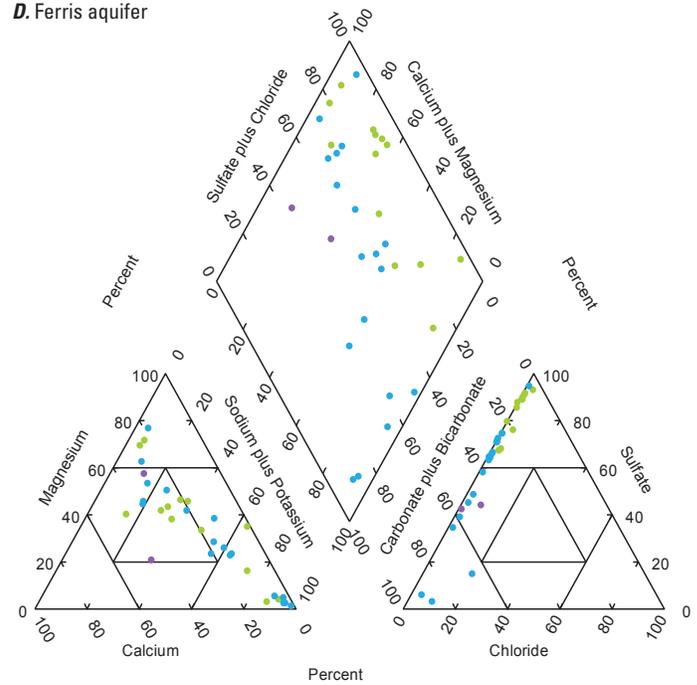
B. Browns Park aquifer



C. Hanna aquifer



D. Ferris aquifer



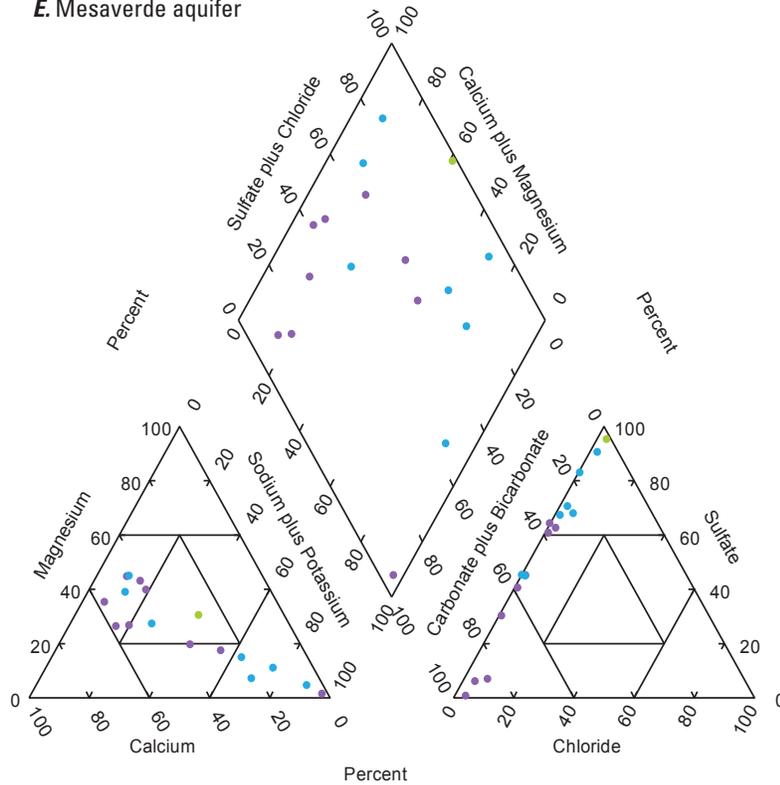
EXPLANATION

Total dissolved-solids concentration, in milligrams per liter, and U.S. Geological Survey salinity classification (Heath, 1983)

- Less than or equal to 999; fresh
- 1,000–2,999; slightly saline
- 3,000–9,999; moderately saline
- 10,000–34,999; very saline
- Greater than or equal to 35,000; briny

Appendix G2. Trilinear diagrams showing major-ion composition and total dissolved-solids concentrations for environmental groundwater samples from the central Wyoming basins (south).

E. Mesaverde aquifer



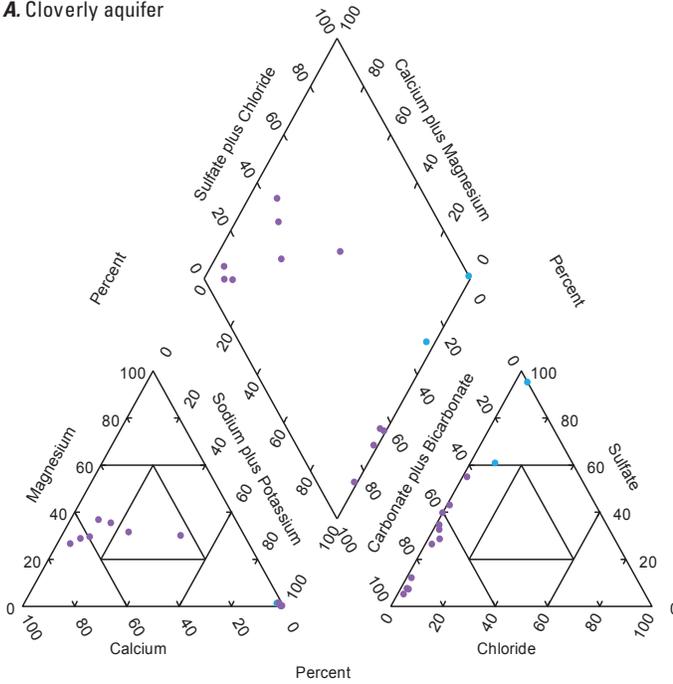
EXPLANATION

Total dissolved-solids concentration, in milligrams per liter, and U.S. Geological Survey salinity classification (Heath, 1983)

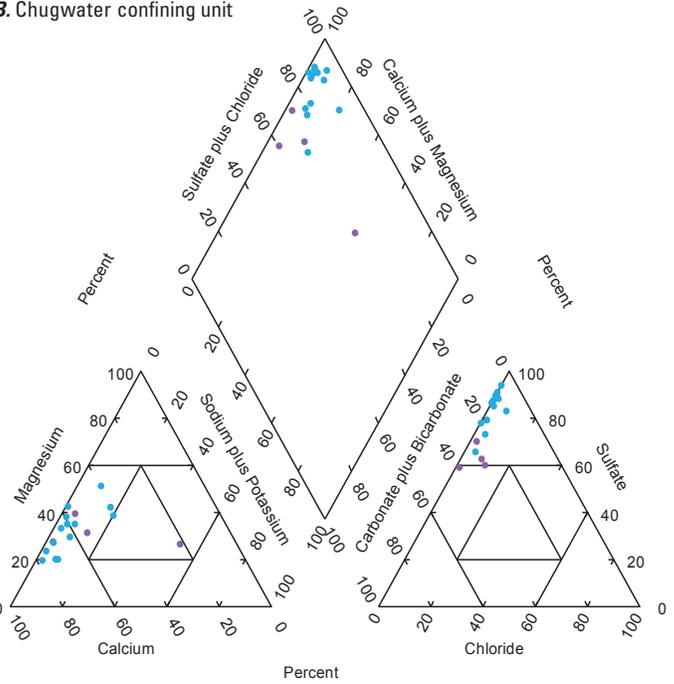
- Less than or equal to 999; fresh
- 1,000–2,999; slightly saline
- 3,000–9,999; moderately saline
- 10,000–34,999; very saline
- Greater than or equal to 35,000; briny

Appendix G2. Trilinear diagrams showing major-ion composition and total dissolved-solids concentrations for environmental groundwater samples from the central Wyoming basins (south).
—Continued

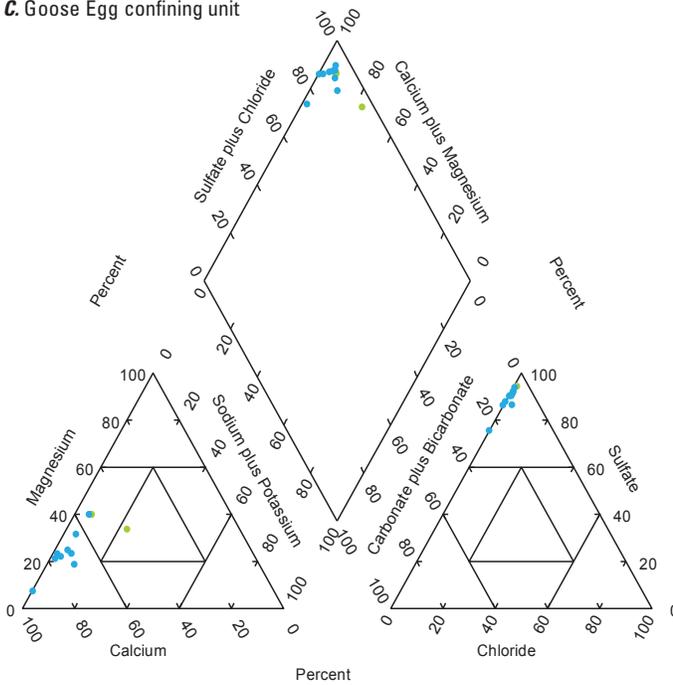
A. Cloverly aquifer



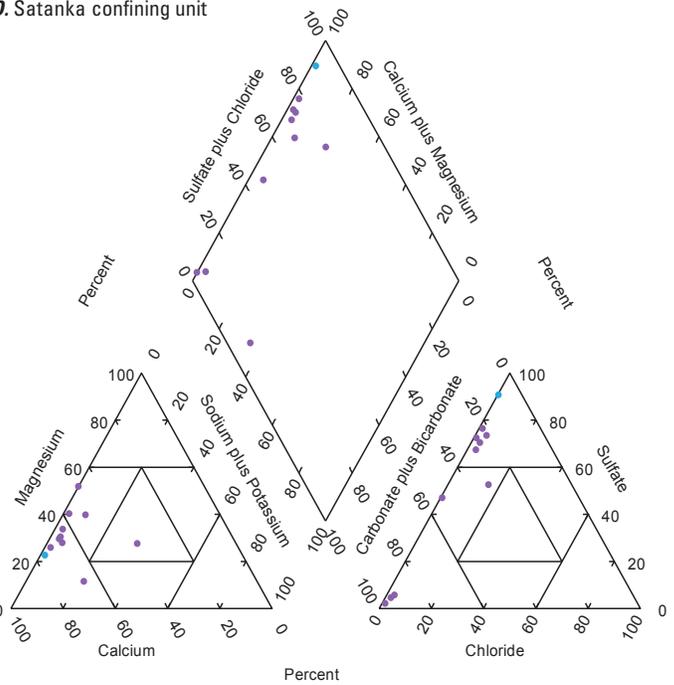
B. Chugwater confining unit



C. Goose Egg confining unit



D. Satanka confining unit



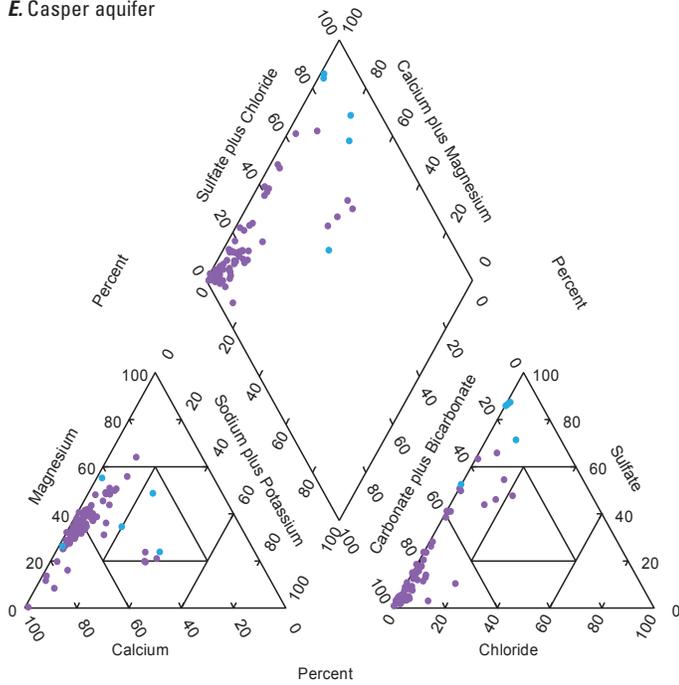
EXPLANATION

Total dissolved-solids concentration, in milligrams per liter, and U.S. Geological Survey salinity classification (Heath, 1983)

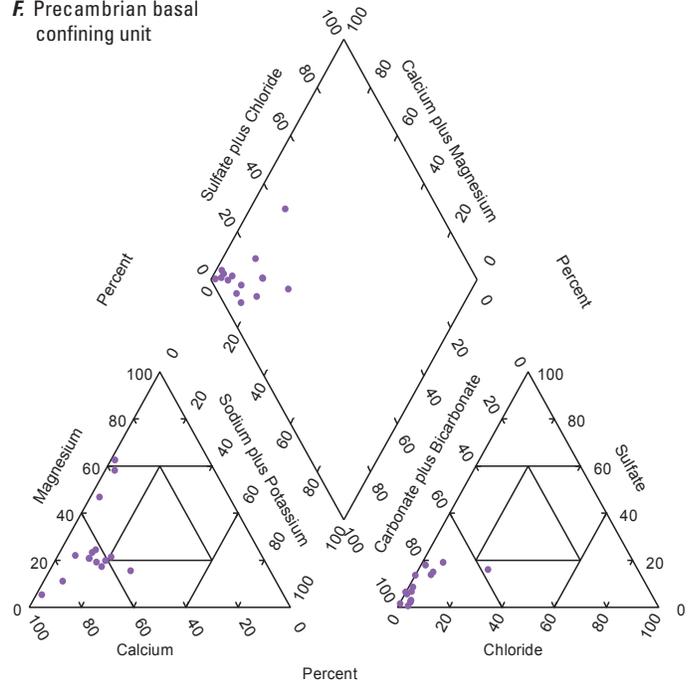
- Less than or equal to 999; fresh
- 1,000–2,999; slightly saline
- 3,000–9,999; moderately saline
- 10,000–34,999; very saline
- Greater than or equal to 35,000; briny

Appendix G3. Trilinear diagrams showing major-ion composition and total dissolved-solids concentrations for environmental groundwater samples from the Laramie Mountains.

E. Casper aquifer



F. Precambrian basal confining unit

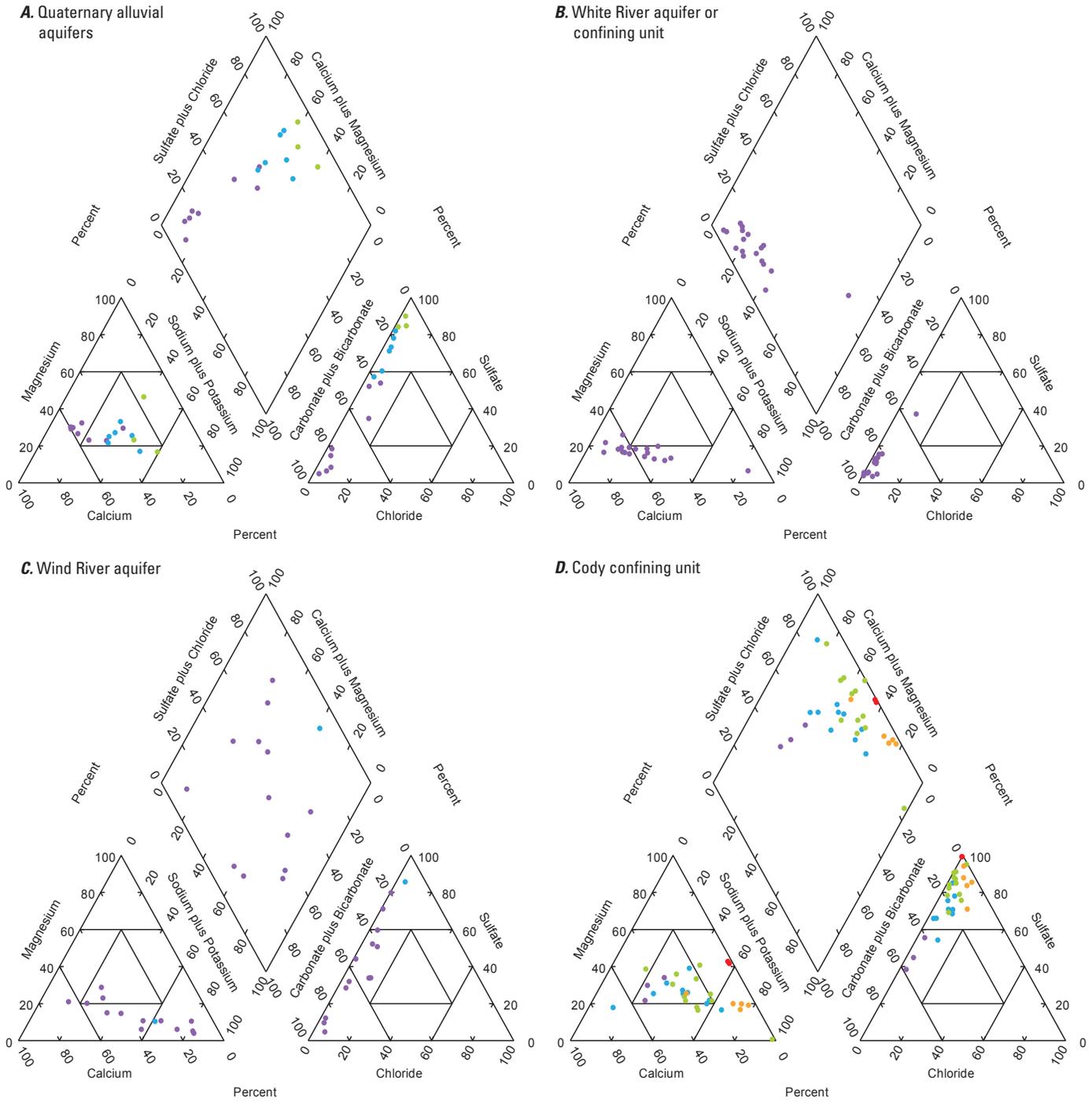


EXPLANATION

Total dissolved-solids concentration, in milligrams per liter, and U.S. Geological Survey salinity classification (Heath, 1983)

- Less than or equal to 999; fresh
- 1,000–2,999; slightly saline
- 3,000–9,999; moderately saline
- 10,000–34,999; very saline
- Greater than or equal to 35,000; briny

Appendix G3. Trilinear diagrams showing major-ion composition and total dissolved-solids concentrations for environmental groundwater samples from the Laramie Mountains.—Continued



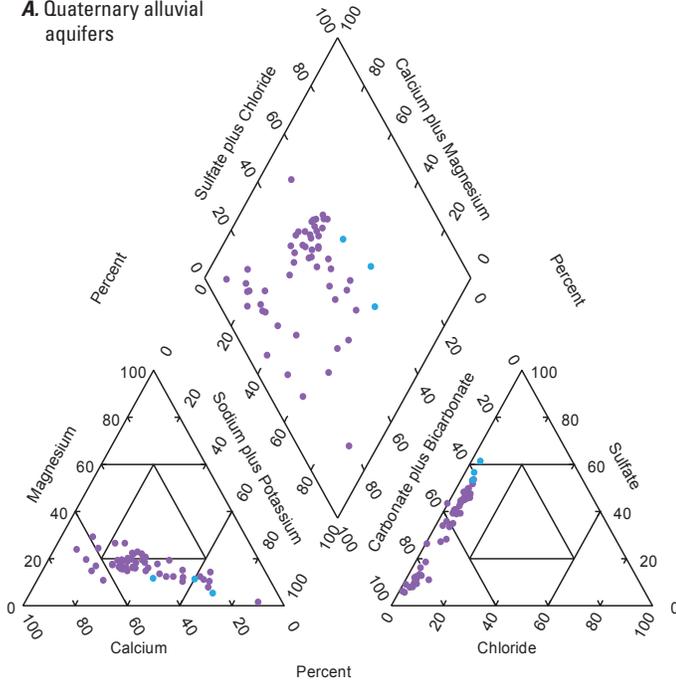
EXPLANATION

Total dissolved-solids concentration, in milligrams per liter, and U.S. Geological Survey salinity classification (Heath, 1983)

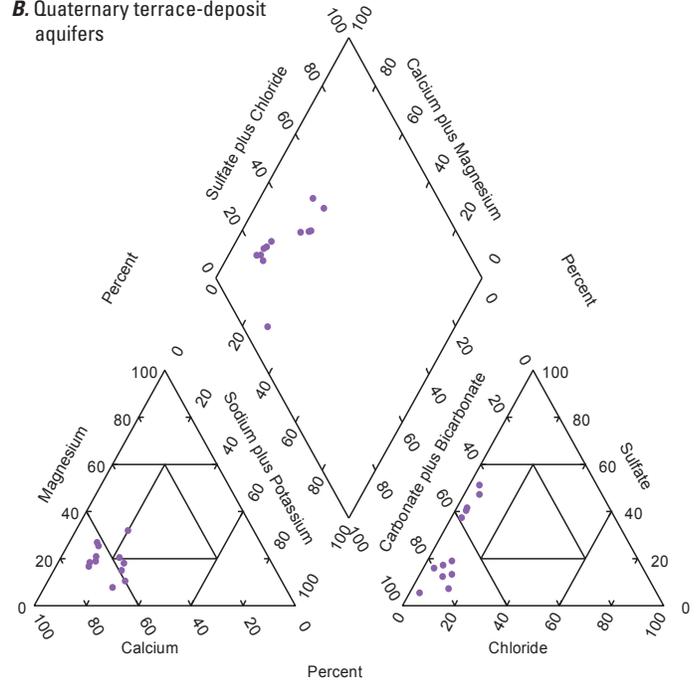
- Less than or equal to 999; fresh
- 1,000–2,999; slightly saline
- 3,000–9,999; moderately saline
- 10,000–34,999; very saline
- Greater than or equal to 35,000; briny

Appendix G4. Trilinear diagrams showing major-ion composition and total dissolved-solids concentrations for environmental groundwater samples from the central Wyoming basins (north).

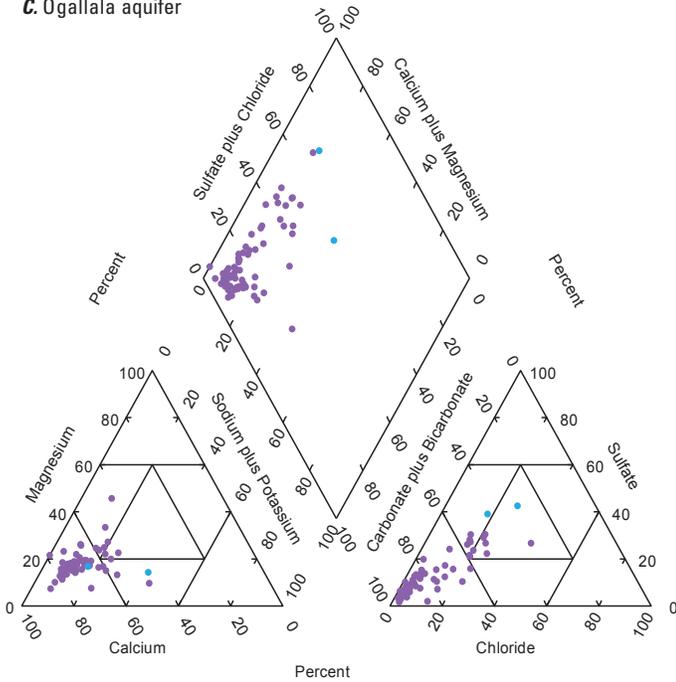
A. Quaternary alluvial aquifers



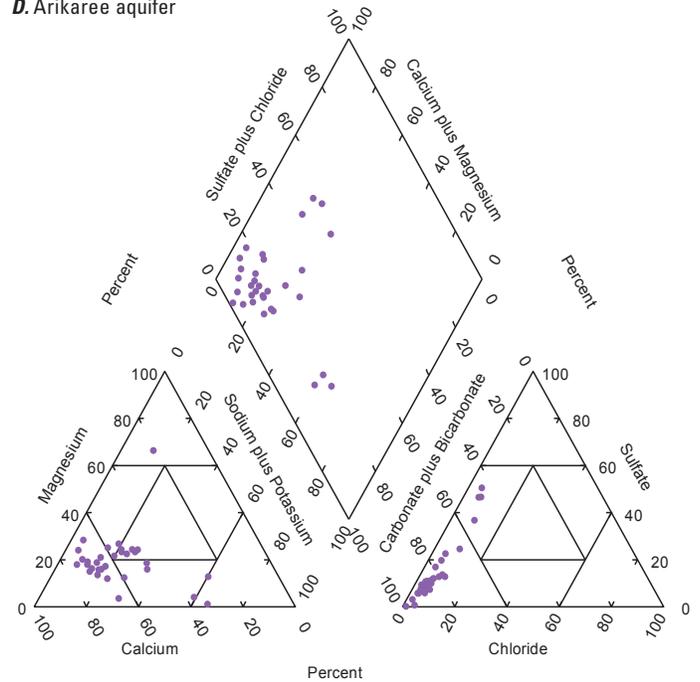
B. Quaternary terrace-deposit aquifers



C. Ogallala aquifer



D. Arikaree aquifer



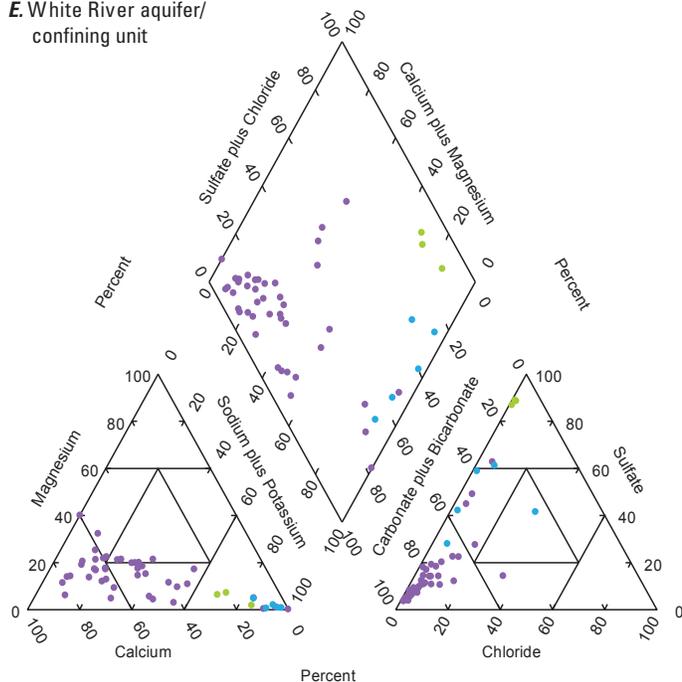
EXPLANATION

Total dissolved-solids concentration, in milligrams per liter, and U.S. Geological Survey salinity classification (Heath, 1983)

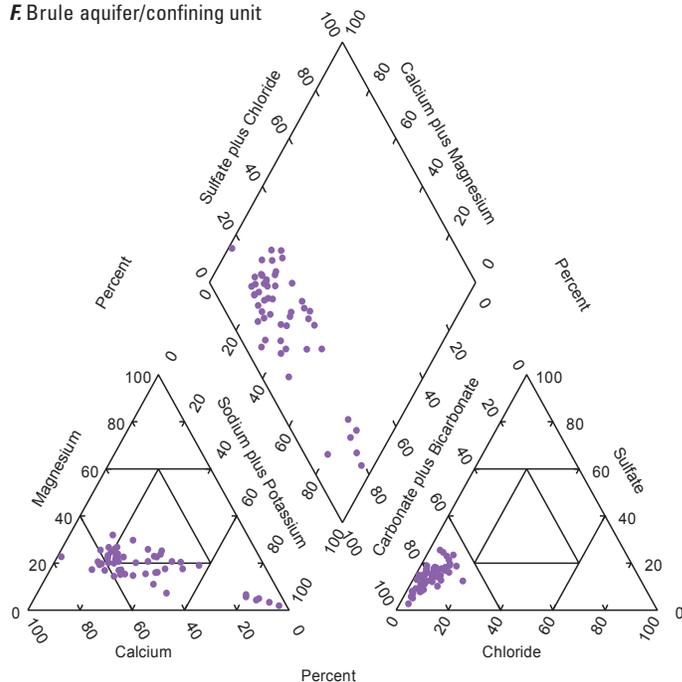
- Less than or equal to 999; fresh
- 1,000–2,999; slightly saline
- 3,000–9,999; moderately saline
- 10,000–34,999; very saline
- Greater than or equal to 35,000; briny

Appendix G5. Trilinear diagrams showing major-ion composition and total dissolved-solids concentrations for environmental groundwater samples from the Great Plains.

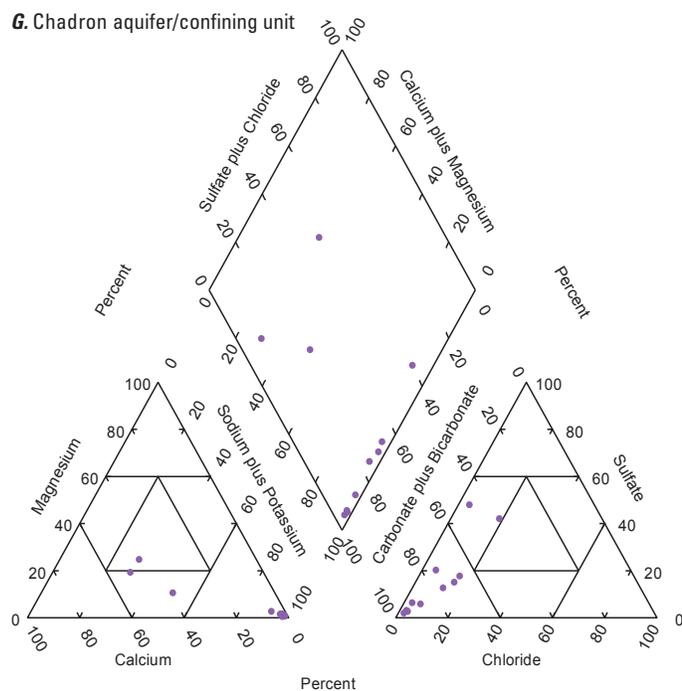
**E. White River aquifer/
confining unit**



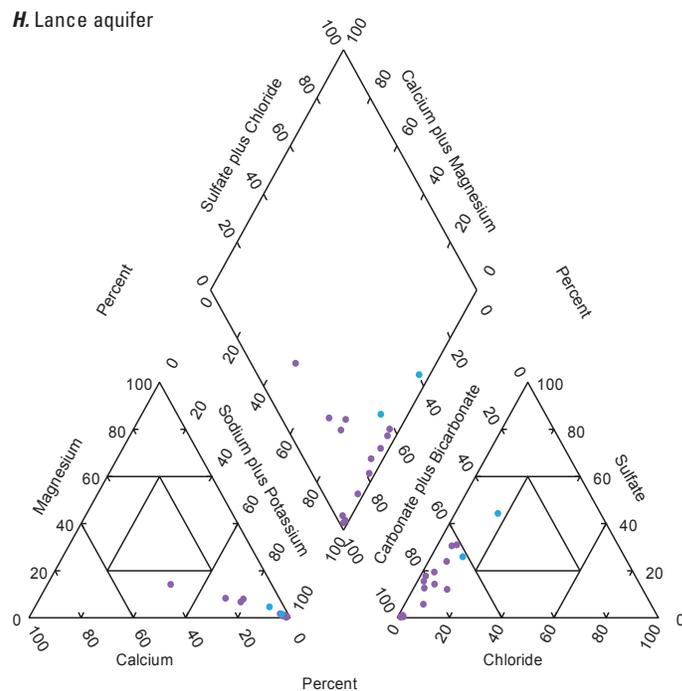
F. Brule aquifer/confining unit



G. Chadron aquifer/confining unit



H. Lance aquifer



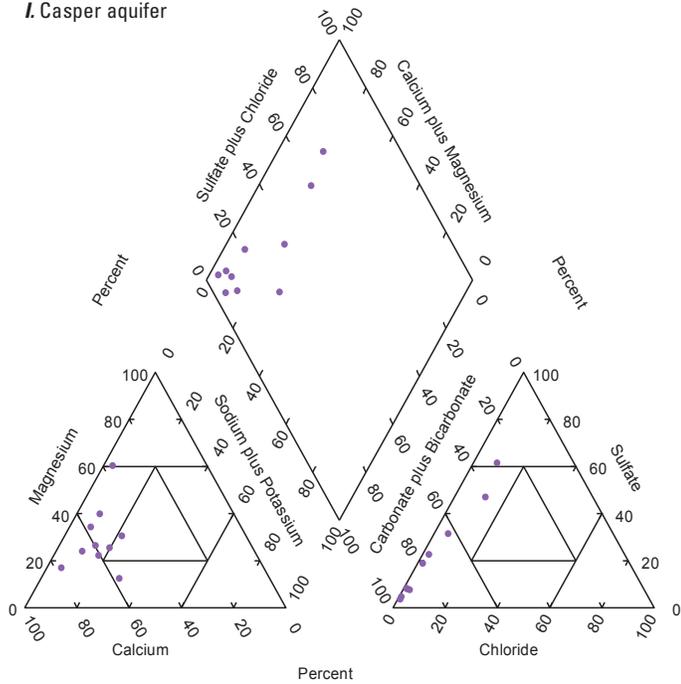
EXPLANATION

**Total dissolved-solids concentration, in milligrams per liter, and
U.S. Geological Survey salinity classification (Heath, 1983)**

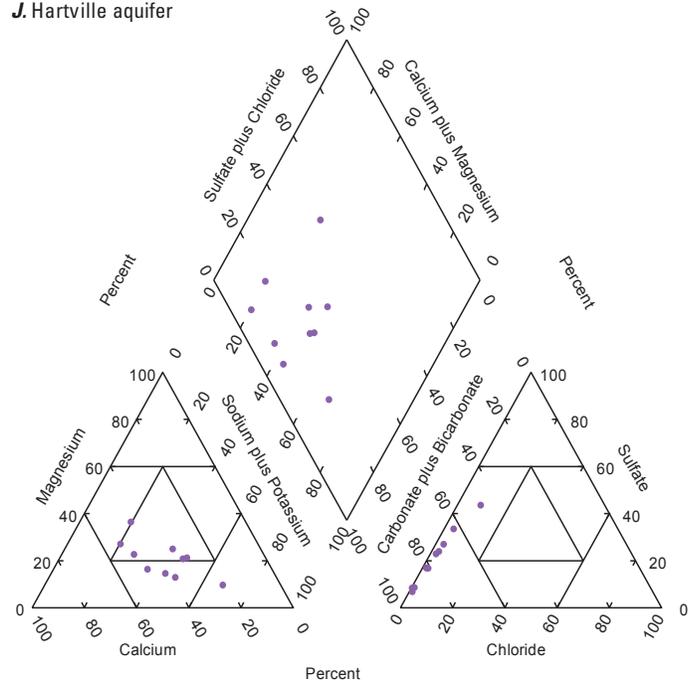
- Less than or equal to 999; fresh
- 1,000–2,999; slightly saline
- 3,000–9,999; moderately saline
- 10,000–34,999; very saline
- Greater than or equal to 35,000; briny

Appendix G5. Trilinear diagrams showing major-ion composition and total dissolved-solids concentrations for environmental groundwater samples from the Great Plains.—Continued

I. Casper aquifer



J. Hartville aquifer



EXPLANATION

Total dissolved-solids concentration, in milligrams per liter, and U.S. Geological Survey salinity classification (Heath, 1983)

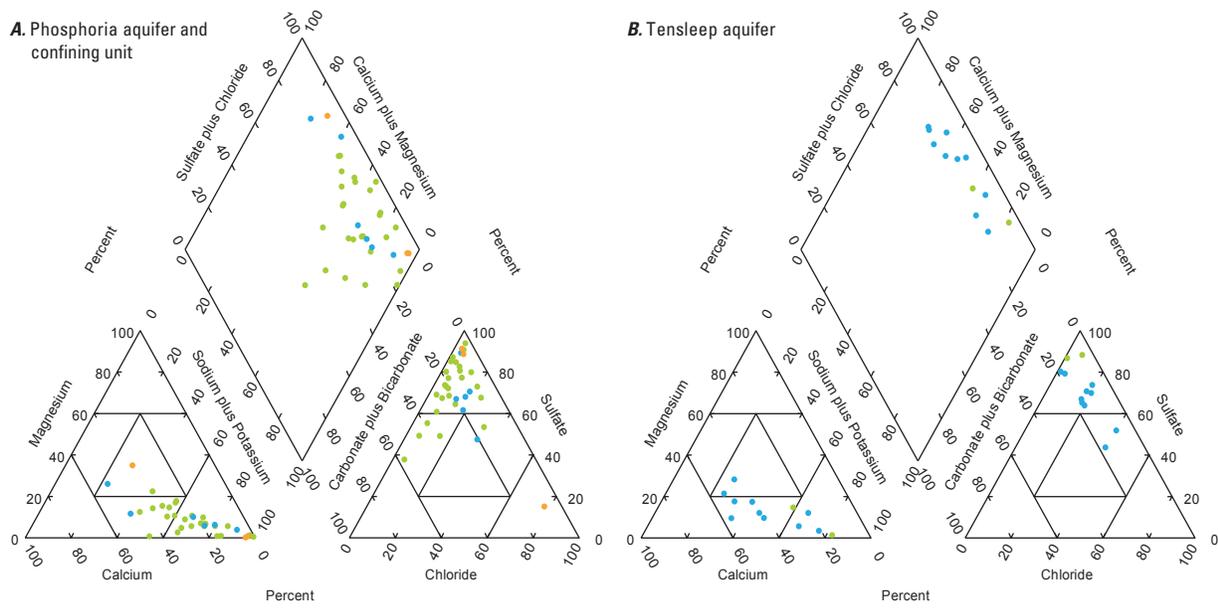
- Less than or equal to 999; fresh
- 1,000–2,999; slightly saline
- 3,000–9,999; moderately saline
- 10,000–34,999; very saline
- Greater than or equal to 35,000; briny

Appendix G5. Trilinear diagrams showing major-ion composition and total dissolved-solids concentrations for environmental groundwater samples from the Great Plains.—Continued

Appendix H

Trilinear Diagrams for Produced Water Samples

Laura L. Hallberg, and Melanie L. Clark



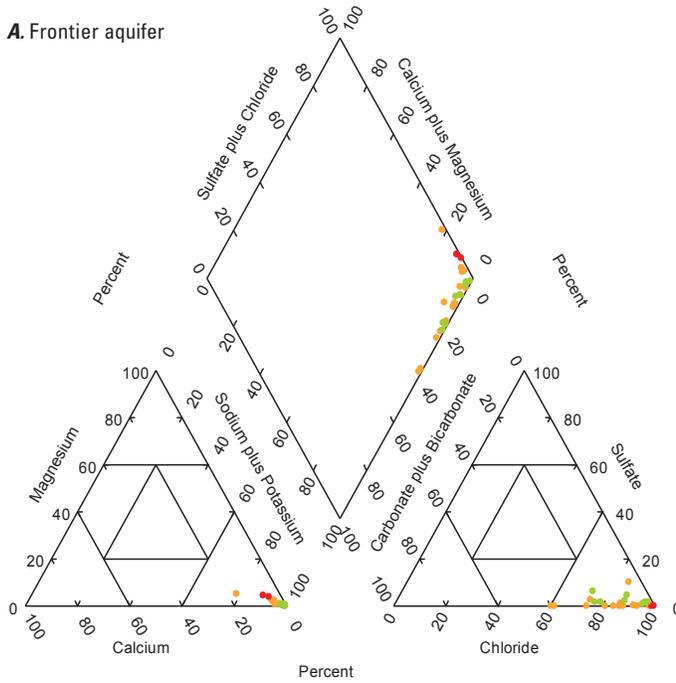
EXPLANATION

Total dissolved-solids concentration, in milligrams per liter, and U.S. Geological Survey salinity classification (Heath, 1983)

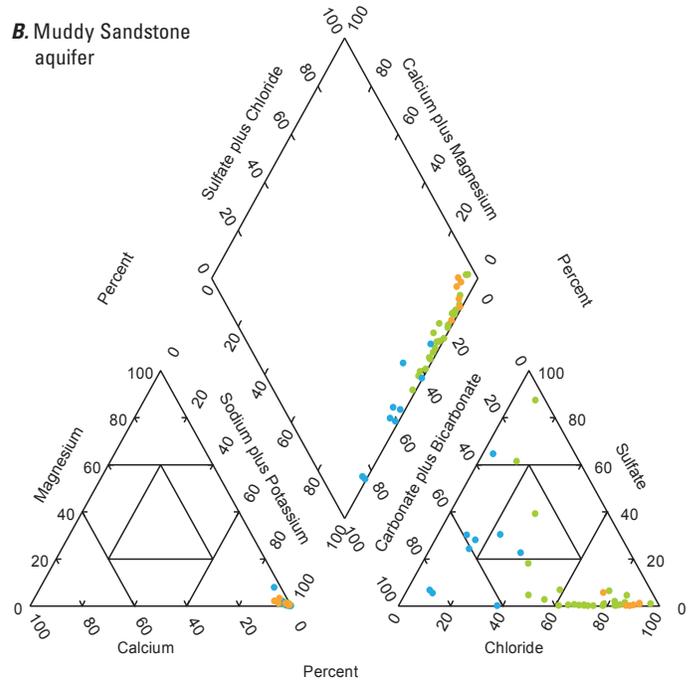
- Less than or equal to 999; fresh
- 1,000–2,999; slightly saline
- 3,000–9,999; moderately saline
- 10,000–34,999; very saline
- Greater than or equal to 35,000; briny

Appendix H1. Trilinear diagrams showing major-ion composition and total dissolved-solids concentrations for produced groundwater samples from the Sweetwater Arch.

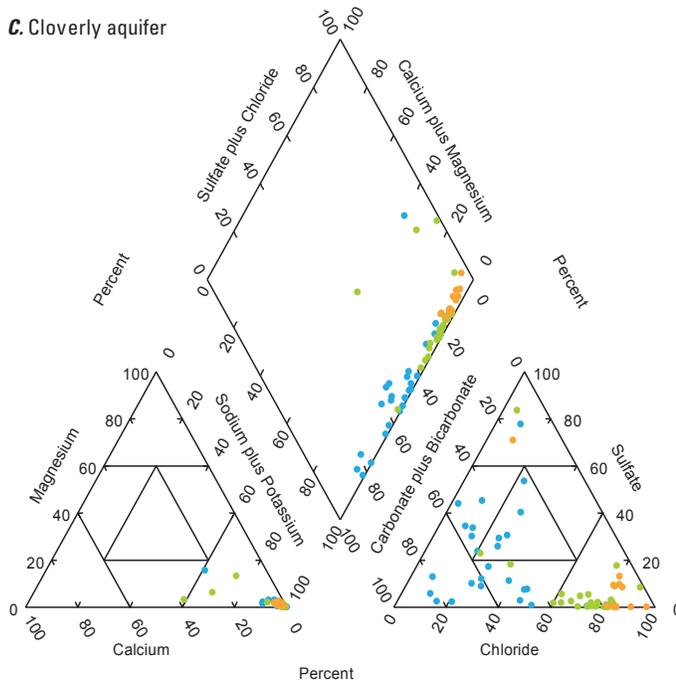
A. Frontier aquifer



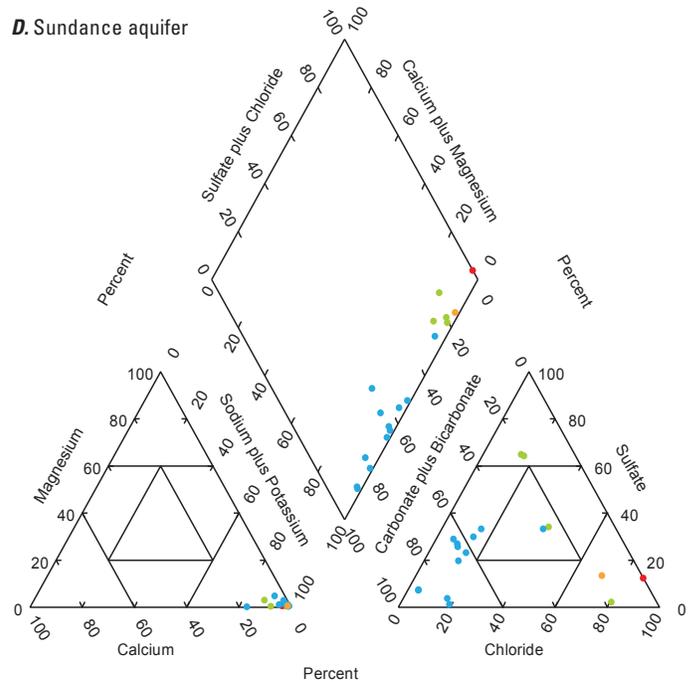
B. Muddy Sandstone aquifer



C. Cloverly aquifer



D. Sundance aquifer



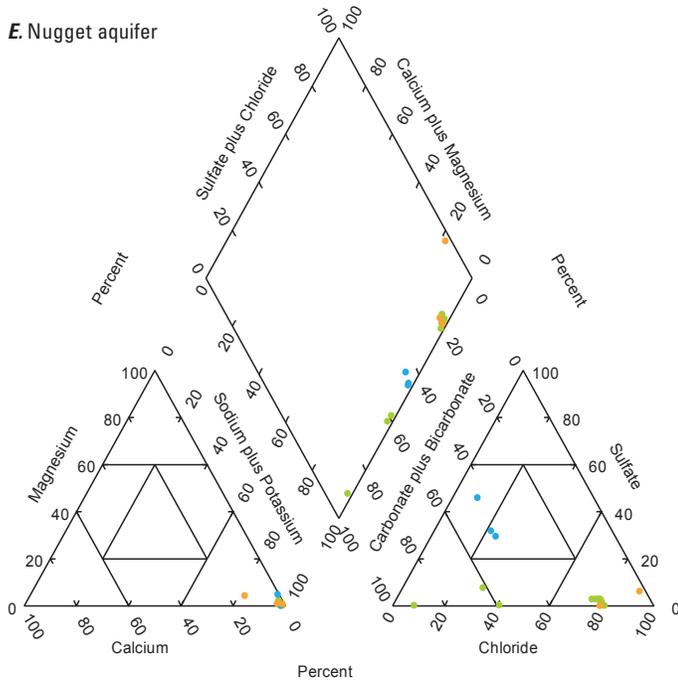
EXPLANATION

Total dissolved-solids concentration, in milligrams per liter, and U.S. Geological Survey salinity classification (Heath, 1983)

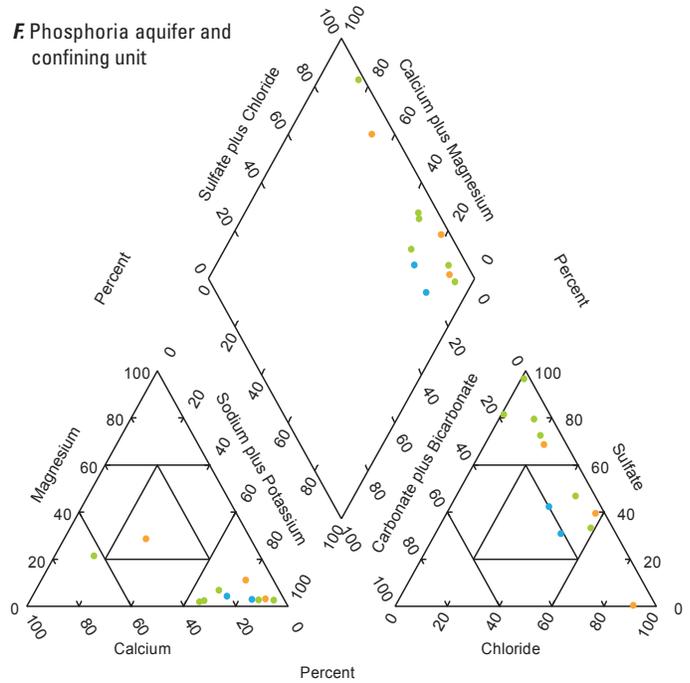
- Less than or equal to 999; fresh
- 1,000–2,999; slightly saline
- 3,000–9,999; moderately saline
- 10,000–34,999; very saline
- Greater than or equal to 35,000; briny

Appendix H2. Trilinear diagrams showing major-ion composition and total dissolved-solids concentrations for produced groundwater samples from the central Wyoming basins (south).

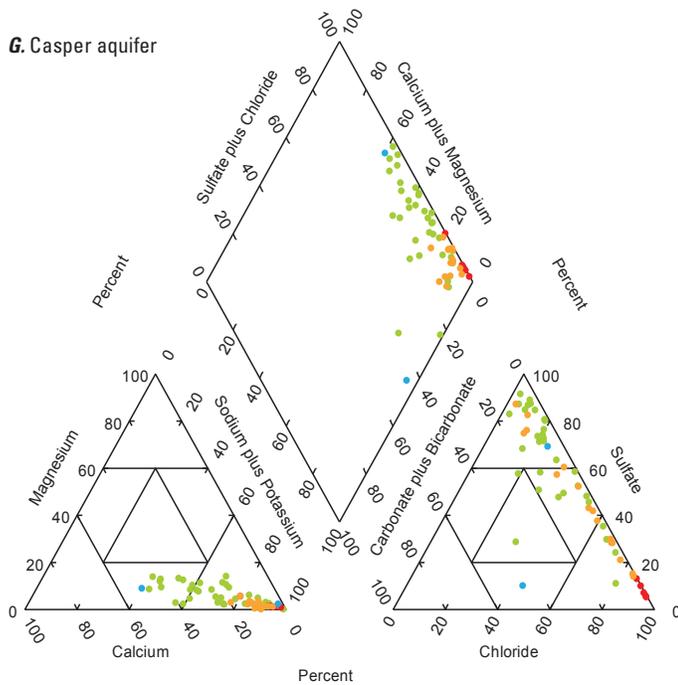
E. Nugget aquifer



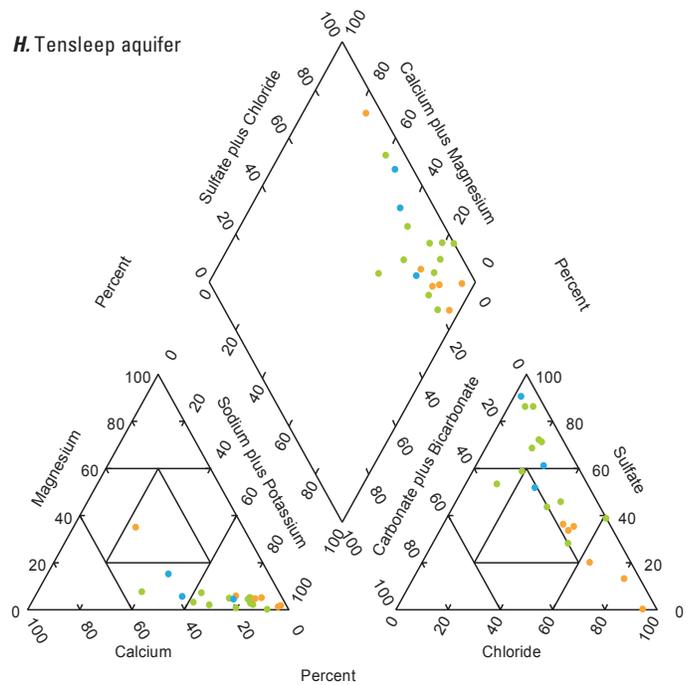
F. Phosphoria aquifer and confining unit



G. Casper aquifer



H. Tensleep aquifer



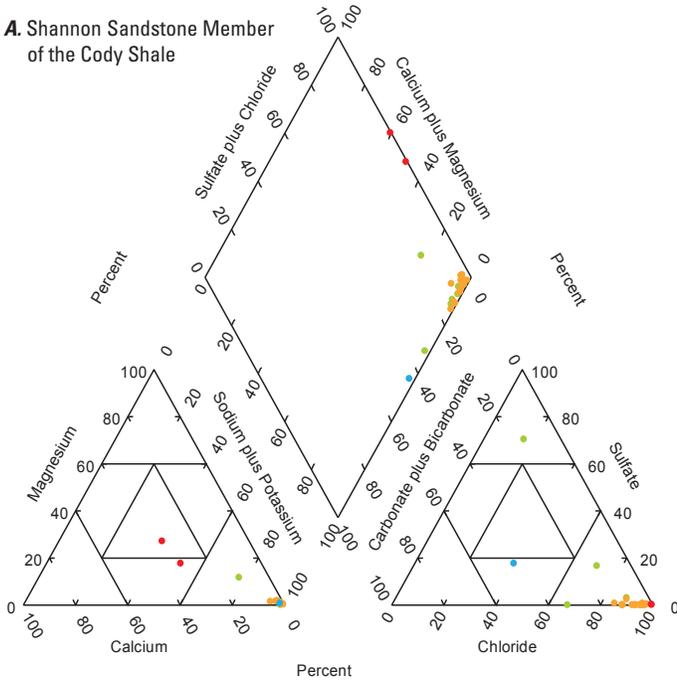
EXPLANATION

Total dissolved-solids concentration, in milligrams per liter, and U.S. Geological Survey salinity classification (Heath, 1983)

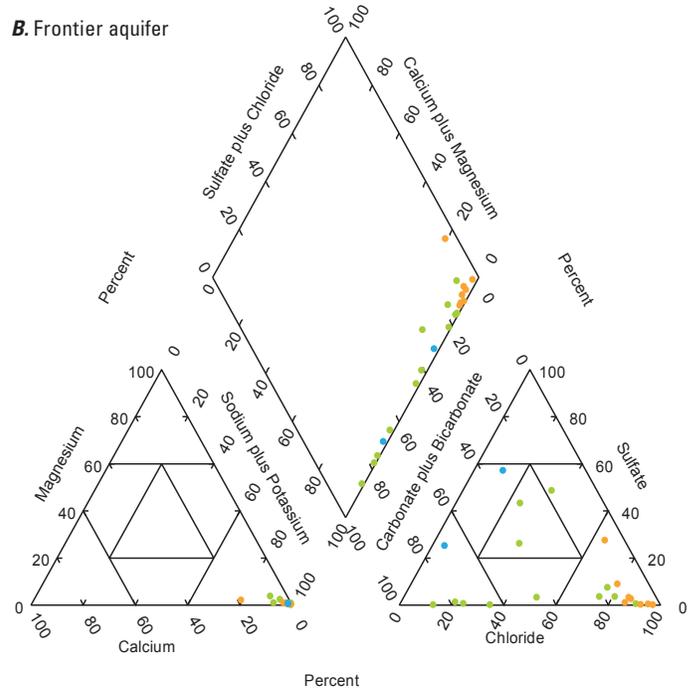
- Less than or equal to 999; fresh
- 1,000–2,999; slightly saline
- 3,000–9,999; moderately saline
- 10,000–34,999; very saline
- Greater than or equal to 35,000; briny

Appendix H2. Trilinear diagrams showing major-ion composition and total dissolved-solids concentrations for produced groundwater samples from the central Wyoming basins (south).—Continued

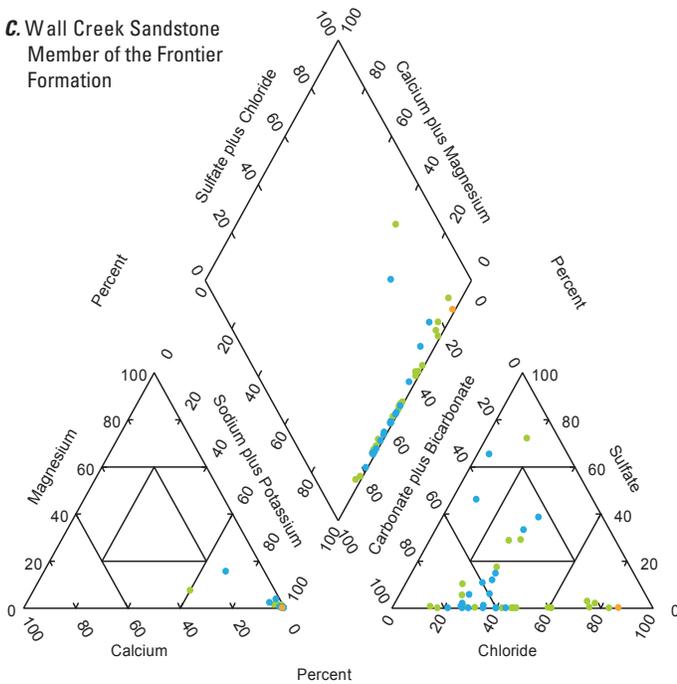
A. Shannon Sandstone Member of the Cody Shale



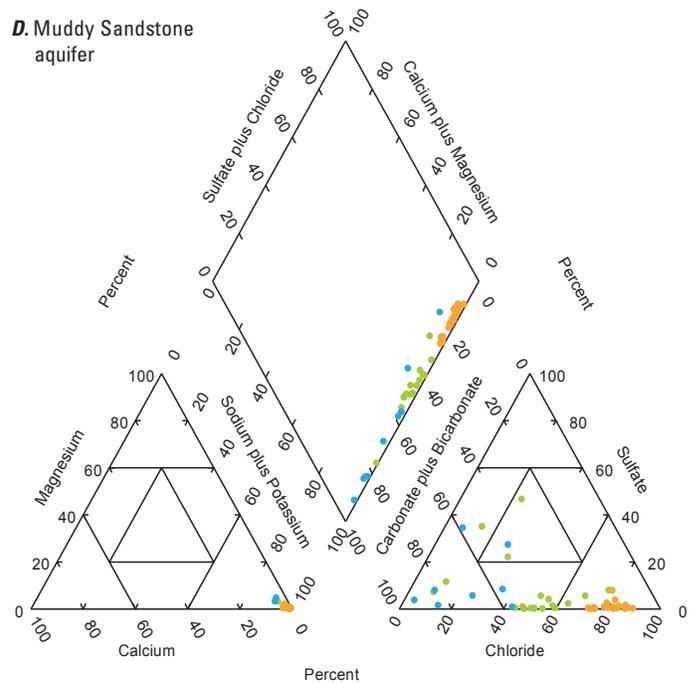
B. Frontier aquifer



C. Wall Creek Sandstone Member of the Frontier Formation



D. Muddy Sandstone aquifer



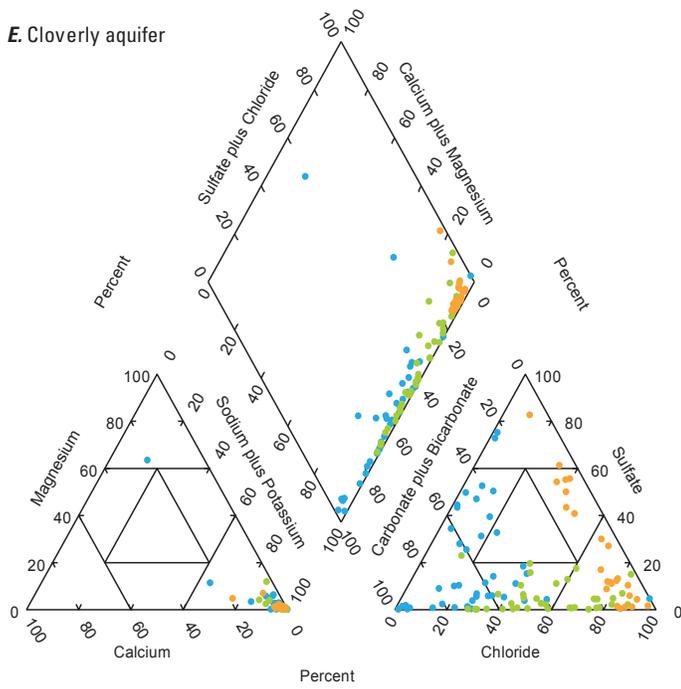
EXPLANATION

Total dissolved-solids concentration, in milligrams per liter, and U.S. Geological Survey salinity classification (Heath, 1983)

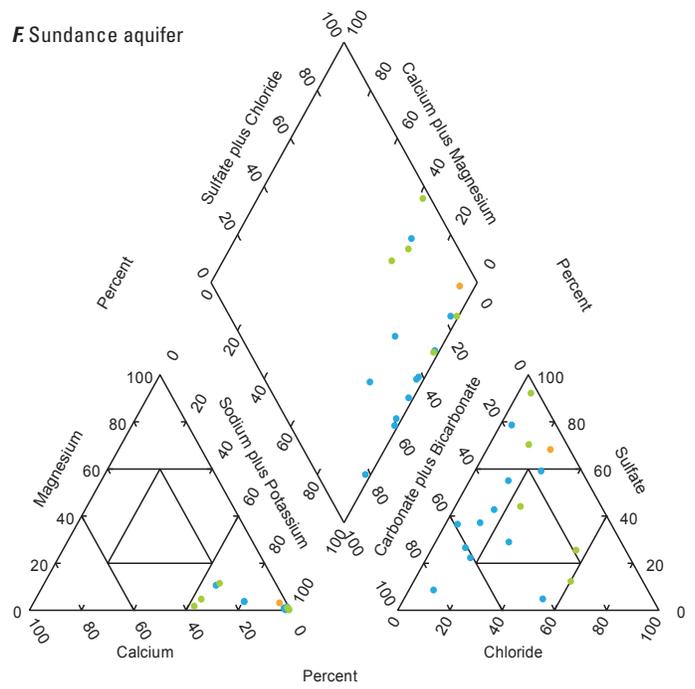
- Less than or equal to 999; fresh
- 1,000–2,999; slightly saline
- 3,000–9,999; moderately saline
- 10,000–34,999; very saline
- Greater than or equal to 35,000; briny

Appendix H3. Trilinear diagrams showing major-ion composition and total dissolved-solids concentrations for produced groundwater samples from central Wyoming basins (north).

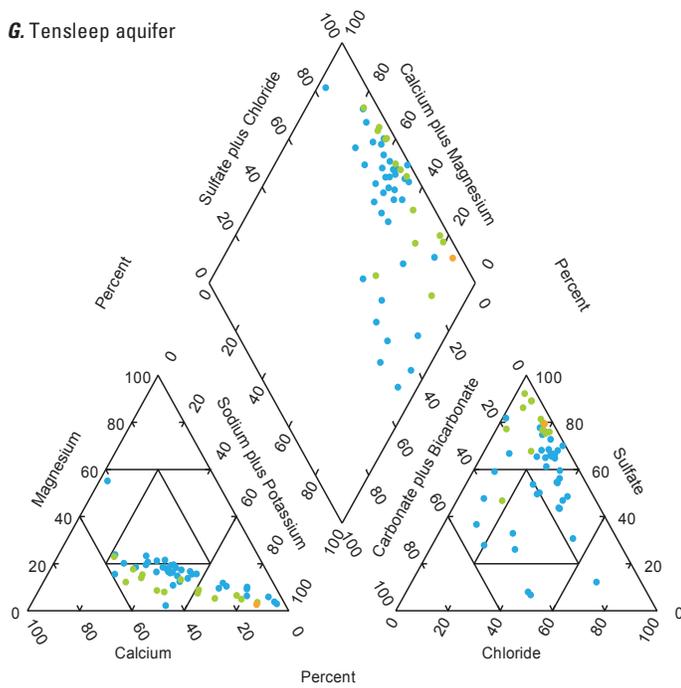
E. Cloverly aquifer



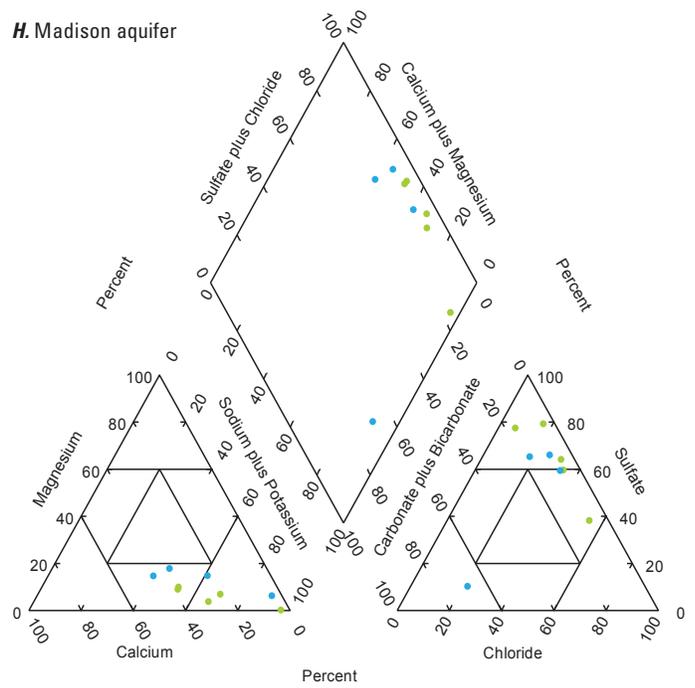
F. Sundance aquifer



G. Tensleep aquifer



H. Madison aquifer



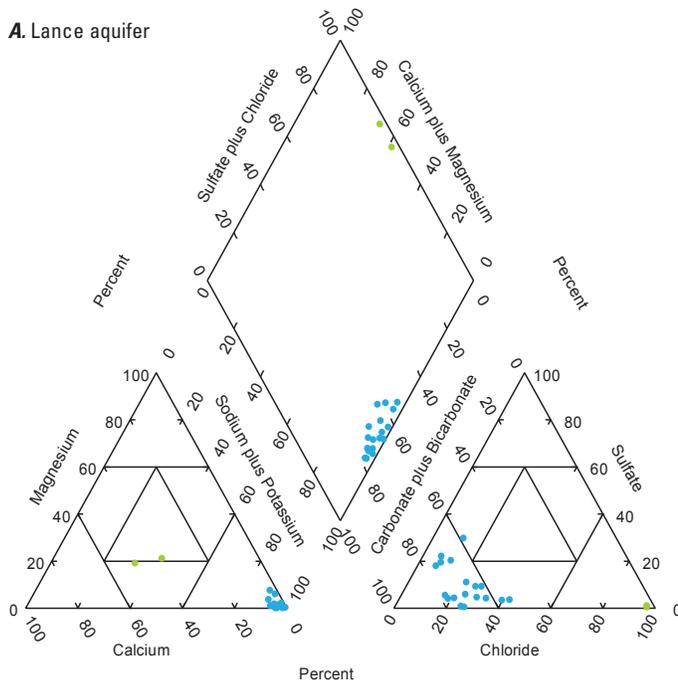
EXPLANATION

Total dissolved-solids concentration, in milligrams per liter, and U.S. Geological Survey salinity classification (Heath, 1983)

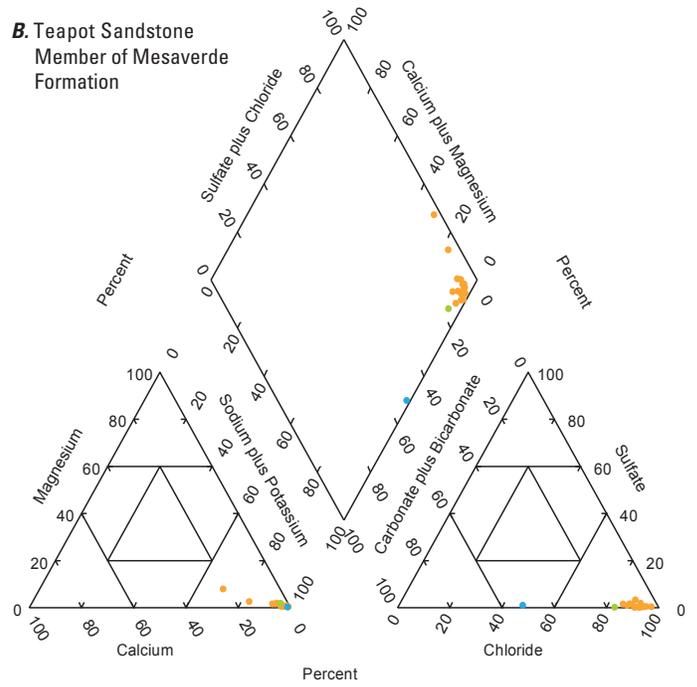
- Less than or equal to 999; fresh
- 1,000–2,999; slightly saline
- 3,000–9,999; moderately saline
- 10,000–34,999; very saline
- Greater than or equal to 35,000; briny

Appendix H3. Trilinear diagrams showing major-ion composition and total dissolved-solids concentrations for produced groundwater samples from the central Wyoming basins (north).—Continued

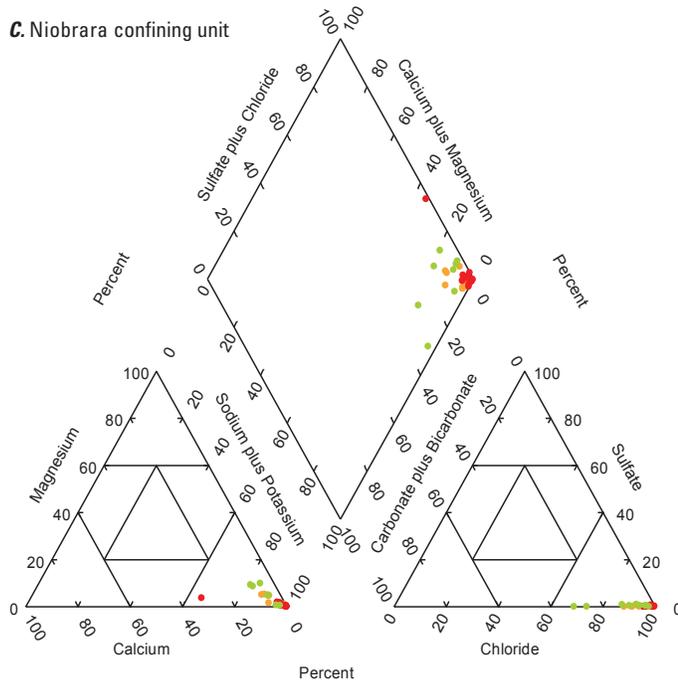
A. Lance aquifer



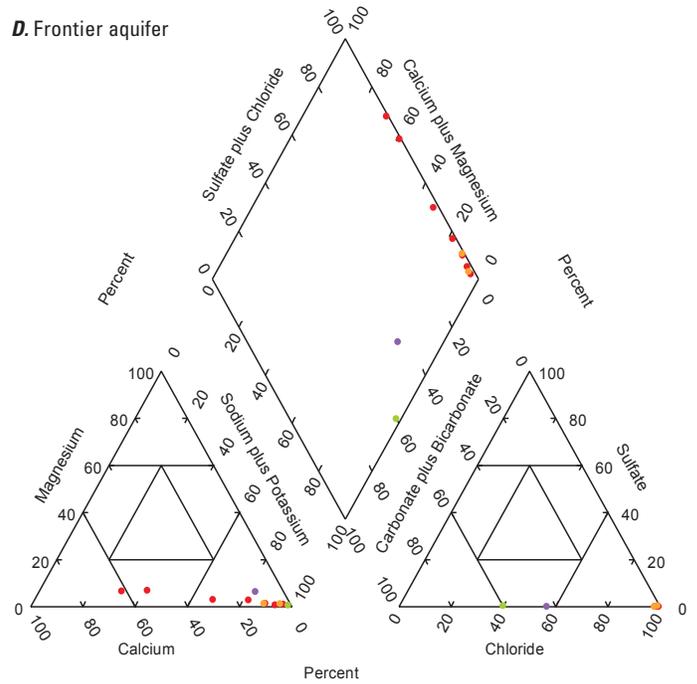
B. Teapot Sandstone Member of Mesaverde Formation



C. Niobrara confining unit



D. Frontier aquifer

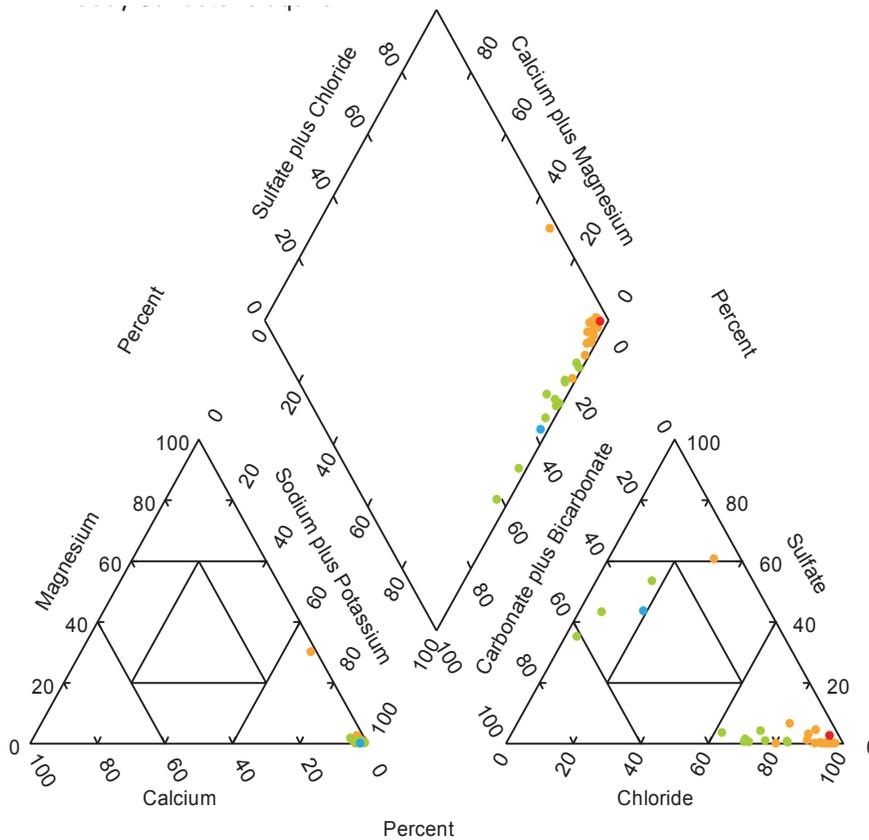


EXPLANATION

Total dissolved-solids concentration, in milligrams per liter, and U.S. Geological Survey salinity classification (Heath, 1983)

- Less than or equal to 999; fresh
- 1,000–2,999; slightly saline
- 3,000–9,999; moderately saline
- 10,000–34,999; very saline
- Greater than or equal to 35,000; briny

Appendix H4. Trilinear diagrams showing major-ion composition and total dissolved-solids concentrations for produced groundwater samples from the Great Plains.



EXPLANATION

Total dissolved-solids concentration, in milligrams per liter, and U.S. Geological Survey salinity classification (Heath, 1983)

- Less than or equal to 999; fresh
- 1,000–2,999; slightly saline
- 3,000–9,999; moderately saline
- 10,000–34,999; very saline
- Greater than or equal to 35,000; briny

Appendix H4. Trilinear diagrams showing major-ion composition and total dissolved-solids concentrations for produced groundwater samples from the Great Plains.—Continued

